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USAAEFA

USAAEFA PROJECT NO. 81 - 16

US ARMY AVIATION SYSTEMS COMMAND

UH - 60A EXPANDED GROSS WEIGHT AND CENTER OF GRAVITY EVALUATION

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AUGUST 1985

FINAL REPORT

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED.

US ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523 - 5000

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER USAAEFA PROJECT NO. 81-16	2. GOVT ACCESSION NO. ADA180404	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) UH-60A EXPANDED GROSS WEIGHT AND CENTER OF GRAVITY EVALUATION		5. TYPE OF REPORT & PERIOD COVERED FINAL 9 JUNE-22 NOVEMBER 1983
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) ROBERT A. WILLIAMS ROBERT MACMULLIN, JOSEPH C. MIESS EDWARD J. TAVARES, GARY L. SKINNER ROBERT M. BUCKANIN, MICHAEL K. HERBST		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US ARMY AVN ENGINEERING FLIGHT ACTIVITY EDWARDS AIR FORCE BASE, CA 93523-5000		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS US ARMY AVIATION SYSTEMS COMMAND 4300 GOODFELLOW BOULEVARD ST. LOUIS, MO 63120-1798		12. REPORT DATE AUGUST 1985
		13. NUMBER OF PAGES 126
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Center of Gravity Envelope
Equivalent Flat Plate Area
Expanded Gross Weight
Handling Qualities
Specification Noncompliances
UH-60A Helicopter

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Testing was conducted to obtain performance and handling qualities at the limits of the expanded gross weight and center of gravity (cg) envelope of the UH-60A helicopter. A total of 38.5 productive flight hours were flown at Edwards Air Force Base, California between 9 June and 22 November 1983. Equivalent flat plate area was minimum with the cg at a fuselage station (FS) of approximately 360 and increased at a more forward and aft cg tested (FS 347 and 366). One deficiency, three shortcomings, and three Prime Item Development Specification

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) noncompliances were identified. One shortcoming, neutral stick-fixed static longitudinal stability in intermediate rated power climb, was associated with envelope expansion. The 4-per-rotor-revolution vibration characteristics, previously identified as a shortcoming, generally were unaffected by increasing gross weight but were aggravated by moving the longitudinal cg further aft. Except for the shortcoming pertaining to neutral static longitudinal stability, the handling qualities were essentially unchanged from those previously reported.

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INTRODUCTION

BACKGROUND

1. The Airworthiness and Flight Characteristics (A&FC) test of the production UH-60A, was completed in September 1981 by the US Army Aviation Engineering Flight Activity (USAAEFA). Testing during the A&FC ranged from primary mission gross weight of 16,260 pounds (lb) to the maximum alternate gross weight of 20,250 lb. Since the completion of the A&FC, a mission has developed requiring additional testing up to 22,000 lb and at a center of gravity (cg) outside the current envelope limits. Sikorsky Aircraft (SA) Division of United Technologies conducted structural, dynamics, flying qualities and height-velocity testing at the expanded gross weight and cg conditions. To evaluate the effects of the SA proposed envelope, additional handling qualities and performance testing was required. In October 1981, USAAEFA was tasked by the US Army Aviation Research and Development Command (ref 1, app A) to plan, conduct, and report on the handling qualities and performance of the UH-60A in the proposed configurations. Due to the priorities of other UH-60A programs, this evaluation was not begun until June 1983.

TEST OBJECTIVES

2. The objectives of this evaluation were as follows:

a. To obtain sufficient performance data in the proposed expanded cg and gross weight envelope for inclusion in the operator's manual.

b. To obtain sufficient handling qualities data for inclusion in the operator's manual.

c. To determine compliance with the applicable paragraphs of the Prime Item Development Specification (PIDS) (ref 2, app A).

DESCRIPTION

3. The test helicopter, UH-60A US Army S/N 77-22716 is a first year production Black Hawk and is a twin engine, single main rotor helicopter with nonretractable wheel-type landing gear capable of transporting cargo, 11 combat troops, and weapons during day, night, visual meterological conditions, and instrument meterological conditions (IMC). Primary mission gross weight is 16,260 lb and the present maximum alternate gross weight is 20,250 lb. The proposed maximum gross weight is increased to 22,000 lb and the cg expanded aft as shown in figure 1,

appendix B. The UH-60A is powered by two General Electric T700-GE-700 turboshaft engines each having an installed power available (30 minute limit) of 1553 shaft horsepower (SHP) (power turbine speed of 20,900 revolutions per minute (rpm)) at sea level, standard-day static conditions. Installed dual-engine power is transmission limited to 2828 SHP. The T700-GE-700 engine incorporates a history recorder, automatic turbine gas temperature limiter, power turbine speed limiter, gas generator speed limiter, automatic torque-matching capability, and various diagnostic systems. The aircraft also has an automatic flight control system (AFCS) and a command instrument system. The test aircraft incorporated prototype airspeed and stabilator modifications developed during USAAEFA Project No. 82-09 (ref 3, app A) to improve the UH-60A airspeed system. A more detailed description of the UH-60A is included in appendix B and additional descriptions can be found in the operator's manual (ref 4).

TEST SCOPE

4. All flight testing was conducted at Edwards Air Force Base, California (2302 feet). A total of 38 flights were conducted between 9 June and 22 November 1983 for a total of 60.0 flight hours of which 38.5 were productive. USAAEFA calibrated and maintained all the test instrumentation and performed all required maintenance on the helicopter. Flight restrictions and operating limitations observed during the evaluation are contained in the operator's manual (ref 4, app A) and the airworthiness release (ref 5). Testing was conducted in accordance with the test plan (ref 6) at the conditions shown in table 1.

TEST METHODOLOGY

5. A detailed listing of the test instrumentation is contained in appendix C. Established flight test techniques and data reduction procedures were used (refs 7 and 8, app A) and are described in appendix D. Level flight performance results from USAAEFA Project No. 83-24 (ref 9) were used to augment test data. A Handling Qualities Rating Scale (HQRS) (fig. 1, app D) was used to augment pilot comments relative to aircraft handling qualities. The flight test data were obtained from test instrumentation displayed on the instrument panel and recorded by onboard magnetic tape recording equipment. Real time telemetry monitoring of selected data parameters was used during certain tests.

Table 1. Test Conditions[1]

Type	Average Gross Weight (lb)	Average Longitudinal Center of Gravity (FS)	Average Density Altitude (ft)	Trim Airspeed (knots)
Level Flight Performance[2]	14,470 to 21,690 18,790 to 21,620 16,500 21,500	347.1 360.1 366.7 347.1	6610 to 13,840 9430 to 11,420 6790 to 13,210 4400 to 9600	51 to 160[3] 52 to 158[3] 50 to 164[3] 75, 90, 117, 140[3]
Control Positions in Trimmed Forward Flight	15,920 and 21,660 21,260 16,480	347.2 360.1 364.9	8920 and 11,500 9460 10,220	35 to 134[4] 45 to 110[4] 46 to 139[4]
Static Longitudinal Stability	21,700 16,660	360.5 365.1	6000 6500	77 and 109[4] 80 and 144[4]
Static Lateral-Directional Stability	21,700 16,800	360.3 365.7	6000 6500	80 and 121[4] 80 and 141[4]
Maneuvering Stability	21,100 16,650	360.4 365.3	6600 6900	77 and 107[4] 77 and 141[4]
Dynamic Stability and Controllability	16,600 21,600	363.8 360.3	2100 and 6300 6000	0, 80, 142[4] 77 and 110[4]
Low Speed Flight	15,900	363.6	2100	0 to 35[3]
System Failures	16,250	365.5	6700	75 and 142[4]
Vibrations	16,200 16,560 21,380 21,330	347.1 365.4 347.1 360.2	13,860 13,220 6620 9380	45 to 125[4] 44 to 149[4] 46 to 120[4] 45 to 109[4]

NOTES:

[1]Tests conducted in the normal utility configuration, approximate mid lateral center of gravity, automatic flight control system ON, and 100 percent main rotor speed. The pitch bias actuator was locked and centered for handling qualities conducted at heavy weight.
[2]Tests conducted at a referred rotor speed of 258 rpm.
[3]Knots true airspeed.
[4]Knots calibrated airspeed.

RESULTS AND DISCUSSION

GENERAL

6. Tests were conducted on the UH-60A helicopter to evaluate performance and handling qualities at the limits of the expanded gross weight and cg envelope. Equivalent flat plate area (F_e) was minimum with the cg at a fuselage station (FS) of approximately 360 and increased at FS 347 and 366. One deficiency, three shortcomings, and three PIDS noncompliances were identified. One shortcoming, neutral stick-fixed static longitudinal stability in intermediate rated power (IRP) climb, was associated with envelope expansion. Except for the shortcoming pertaining to neutral static longitudinal stability, the handling qualities were essentially unchanged from those previously reported. The 4-per-rotor-revolution (4/rev) vibration characteristics, previously identified as a shortcoming, generally were unaffected by increasing gross weight but were aggravated by moving the longitudinal cg further aft.

LEVEL FLIGHT PERFORMANCE

7. Level flight performance tests were conducted at the conditions in table 1 to determine power required for airspeeds, altitudes and gross weights at the limits of the expanded cg envelope. The data were obtained in ball-centered flight and corrected for estimated drag of external test instrumentation and instrumentation electrical load.

8. Nondimensional test results are presented in figures 1 through 3, appendix E. The curves on these figures were obtained by converting the nondimensional test results of the sixth year production aircraft presented in USAAEFA Report No. 83-24 (ref 9, app A) to the first year production aircraft utilized during this evaluation. Change in F_e (ΔF_e) of five square feet (ft^2) was subtracted. This value of ΔF_e was previously determined to be valid at the referred rotor speed ($N_2/\sqrt{\theta}$) used in these tests. This difference is summarized as:

1st yr prod A/C = 6th year prod A/C − ESSS fairings (2.5 ft^2)
− M-130 & AN/ALQ-144(V) brackets (1.5 ft^2)
− external drag differences (1 ft^2)

Dimensional level flight test results are presented in figures 4 through 15, appendix E. Test data at an average cg of FS 360.1 indicate a decrease in power required when compared to the non dimensional family of curves at an average cg of FS 347.1. This difference in power required equates to a ΔF_e of 2 ft^2 and substantiates the test results presented in USAAEFA Report

No. 77-17 (ref 10, app A) for a similar change in cg. The decrease in ΔF_e of 2 ft^2 allows reduction in power required of 55 SHP and still maintain cruise speed at 145 knots true airspeed (KTAS) (fig. 10, app E). Test data at an average cg of FS 366.7 indicate no change in power required when compared to the nondimensional curves at a FS of 347.1. Therefore, F_e was minimal at a FS of approximately 360 and increased at FS 347.1 and 366.7. Inherent sideslip (figs. 16 and 17) represents the resultant angle of sideslip associated with ball-centered level flight and was developed using level flight performance data presented in this report (figs. 18 and 19) and in USAAEFA Report No. 83-24. The inherent sideslip family of curves was used as the basis for correction in determining ball-centered flight as described in appendix D.

9. Tests were conducted during this evaluation and during USAAEFA Project No. 83-24 to ascertain the relationship of ΔF_e with sideslip. The data are presented in figure 20, appendix E. Drag changes from zero sideslip are independent of airspeed but vary with C_T. The data indicate that minimum F_e occurs between 4.5 and 7 degrees left sideslip depending on C_T. Coordinated level flight, however, results in a maximum left sideslip of approximately 1 degree.

HANDLING QUALITIES

Control Positions in Trimmed Forward Flight

10. Control positions in trimmed ball-centered forward flight were obtained in conjunction with level flight performance testing at the conditions in table 1. Selected results are presented in figures 21 and 22, appendix E.

11. The variation of longitudinal control position with airspeed during trimmed level flight generally required increasing forward cyclic control with increasing airspeed. At airspeeds below 60 knots calibrated airspeed (KCAS) the variation was neutral to slightly negative (aft cyclic required with increasing airspeed), but not objectionable. Maximum longitudinal trim variation was nearly two inches over the entire airspeed range. At both heavy and light gross weight, maximum changes in longitudinal control position (1-1/2 inches), lateral control position (1/2 inch), and pitch attitude (4 degrees) were minimal for a large cg shift (13 to 18 inches). Control positions (except collective) were mostly unaffected by changes in gross weight. Directional and lateral control positions were essentially unaffected by changes in cg and gross weight. The gradient of directional control position

with airspeed was moderately steep from 40 to 80 KCAS (approximately 0.035 inches/knot). Above 80 KCAS the gradient was shallow and maximum directional trim variation was less than 1/4 inch. Adequate control margins existed in all control axes in trimmed forward flight. Trim pitch attitude remained nearly constant from 40 to 80 KCAS and then decreased linearly approximately 0.05 degree/knot above 80 KCAS. Pitch attitude changes with airspeed were unnoticeable to the pilot. The control positions in forward flight are satisfactory.

12. During the control position and level flight performance evaluations, the yaw trim would randomly drive the right pedal forward significantly increasing the pilot workload to maintain trimmed flight. This problem is not unique to this aircraft (USA S/N 77-22716) but was noted on other UH-60A aircraft including a sixth year production version (USA S/N 82-23748). During IMC this uncommanded directional control input in trimmed flight will require frequent, large (approximately 1/2 inch) pedal inputs making precise heading control (± 3 degrees) unattainable (HQRS 7) and is a deficiency which was previously reported (Preliminary Airworthiness Evaluation III, April 1979 (ref 11, app A), A&FC September 1981 (ref 10); and External Stores Support System A&FC, December 1983 (ref 12)).

Static Longitudinal Stability

13. Static longitudinal stability was evaluated at the conditions shown in table 1. The helicopter was stabilized in ball-centered flight at the desired trim airspeed and flight condition. With the collective control held fixed and rotor speed maintained constant, the helicopter was stabilized at incremental airspeeds about trim. Test results are presented in figures 23 through 26, appendix E.

Level and Descending Flight:

14. Static longitudinal stick-fixed stability, as indicated by the variation of longitudinal cyclic control position with airspeed, was positive (aft longitudinal control displacement at airspeeds slower than trim) except at 144 KCAS in level flight at light weight/aft cg. The gradient of control displacement versus airspeed was steepest near the trim point and generally became shallow or neutral at airspeeds greater than 10 knots from trim. Qualitatively, the pilot had adequate control force cues of airspeed changes about trim. The maximum variation of lateral cyclic and directional pedal control position from trim was approximately 3/4 inch, but was not objectionable to the pilot. Pitch attitude remained essentially constant except in level

flight at light weight/aft cg (trim airspeed 144 KCAS) where the pitch attitude decreased with increasing airspeed. The pilot was able to maintain airspeed within ± 2 knots with minimal effort (HQRS 2). The static longitudinal stability at 144 KCAS in level flight at light weight/aft cg failed to meet the requirement of paragraph 10.3.3.1.3 of the PIDS. However, the static longitudinal stability in level flight and 1000 foot per minute (fpm) descents within 10 knots of trim is satisfactory.

Intermediate Rated Power Climb:

15. Static longitudinal stability was neutral in IRP climbs at 81 KCAS at light weight/aft cg with the pitch bias actuator (PBA) operational (fig. 25). However, at heavy gross weight (21,480 lb) with the PBA centered and locked, the static longitudinal stick-fixed stability was positive (fig. 26). Force cues were minimal at both loadings. Due to collective bias, stabilator programming was noticeably different between the two gross weights in that at heavy weight/aft cg the stabilator programmed about 10 deg more trailing edge (TE) down than at light weight/aft cg as airspeed was decreased below trim. Airspeed was easier to maintain at heavy weight (HQRS 3) than at light weight. At light weight (16,600 lb), airspeed was moderately difficult to maintain (± 5 knots) in that continuous longitudinal cyclic control inputs ($\pm 1/4$ inch every 5 seconds) were required (HQRS 4). The lack of force and position cues with variation in airspeed about trim will increase pilot workload in IMC. The neutral stick-fixed static longitudinal stability at light weight/aft cg in IRP climb is a shortcoming. The aircraft failed the positive stability requirements of para 10.3.3.1.3 of the PIDS in that at light weight/aft cg the longitudinal static stability in the IRP climb condition was neutral.

STATIC LATERAL-DIRECTONAL STABILITY

16. Static lateral-directional stability characteristics were evaluated at the conditions and configurations indicated in table 1. Tests were conducted by trimming the aircraft in ball-centered flight at the desired conditions. With the collective fixed, the aircraft was then stabilized at incremental sideslip angles up to limit sideslip on both sides of trim while maintaining a steady heading at the trim airspeed. Test results are presented in figures 27 through 30, appendix E.

17. Static directional stability, as indicated by the variation of directional control position with sideslip, was positive (increasing left directional control with increasing right

sideslip) at all test conditions and configurations. The directional control variation with sideslip was essentially linear; however, the average directional control gradient was shallower during descents than during climbs (0.05 versus 0.07 inches/degree). The directional stability characteristics of the UH-60A met the requirements of the PIDS (para 10.3.4.1.7) and are satisfactory.

18. Dihedral effect, as indicated by the variation of lateral control position with sideslip was positive (increasing right cyclic control with increasing right sideslip) and essentially linear for all test conditions and configurations. The gradient of lateral cyclic control position versus sideslip was steeper at high speeds (121 and 141 KCAS) than at the other conditions, but was not objectionable. There were no discontinuities in force or position cues and good out-of-trim cues were present. The dihedral effect of the UH-60A met the requirements of the PIDS (para 10.3.4.1.7) and is satisfactory.

19. Sideforce characteristics, as indicated by the variation in bank angle with sidelip, were weak but positive (increasing right bank angle with increasing right sideslip) for all low speed (76 to 83 KCAS) conditions and configurations tested. Because of the control position and force cues, the reduced sideforce cues did not significantly increase the pilot workload. As airspeed was increased to 121 and 141 KCAS, the sideforce cues increased. The sideforce cues, though weak at low airspeeds, were satisfactory and meet the requirements of paragraph 10.3.4.1.7 of the PIDS.

20. A pitch-due-to-sideslip coupling was evident in all conditions and configurations. In all conditions, except high speed (141 KCAS), the longitudinal cyclic position versus sideslip trend was essentially the same (increasing forward longitudinal cyclic control with increasing right sideslip). In high speed flight, this trend reversed itself (increasing aft longitudinal cyclic control with increased right sideslip), but was not noted by the pilots during flight. The pitch-due-to-sideslip coupling was not objectionable.

21. The UH-60A exhibited inherent sideslip angles of approximately 5 degrees right during ball-centered IRP climbs and approximately 5 degrees left during ball-centered 1000 fpm descents. In level flight at all airspeeds above 90 KTAS, the inherent sideslip angle varied from 1 degree left to 2 degrees right sideslip depending upon C_T.

Maneuvering Stability

22. Maneuvering stability was evaluated for two aircraft configurations, lightweight/aft cg and heavyweight/aft cg at the conditions presented in table 1. The maneuvering stability tests were accomplished by initially stabilizing the helicopter in ball-centered level flight at the trim airspeed and then incrementally increasing the load factor by increasing the bank angles in left and right turns. Constant collective control position was maintained in the maneuvers and the pilot attempted to maintain a constant airspeed. Test results are presented in figures 31 and 32, appendix E.

23. The stick-fixed maneuvering stability, as indicated by the variation of longitudinal control position with normal acceleration (g), in the lightweight configuration was positive (increasing aft cyclic control with increasing g) up to 1.6 g at 77 KCAS and essentially neutral for all g levels at 121 KCAS (approximate maximum airspeed in level flight). Between 1.6 and 1.9 g's at 77 KCAS the stick-fixed maneuvering stability was neutral (no change in longitudinal control position with increasing g). During left turns at both trim airspeeds, there was a linear requirement for more left cyclic control as the g levels were increased. In right turns the lateral control position was essentially constant up to 1.6 g's. At g levels above 1.6 for both airspeeds in right turns, the requirement for right cyclic control increased dramatically (approximately 2.5 inches/g) and as a result pilot induced oscillations increased significantly.

24. The heavyweight configuration at 77 KCAS exhibited longitudinal control characteristics similar to the lightweight configuration except that the stick-fixed maneuvering stability became negative (increasing forward longitudinal cyclic control with increasing g) at 1.4 g's. At 107 KCAS (approximate never-exceed airspeed minus 10 knots), the stick-fixed maneuvering stability was essentially neutral during left turns and slightly positive during right turns up to the maximum g level tested (1.7g). In left turns at both trim airspeeds, the lateral cyclic control characteristics were unchanged from those seen in the lightweight configuration. During right turns the lateral cyclic control reversal occurred at approximately 1.4 g's and the control gradient at 107 KCAS increased to 5 inches/g.

25. The time histories presented in figures 33 through 35, appendix E are representative of the maneuvering stability tests performed during this evaluation. At bank angles less than 40 degrees (fig. 33), the pilot was able to maintain precise airspeeds (±1 knot) and bank angles (±1 degree) with minimal

pilot compensation (HQRS 3). As bank angles were increased above 40 degrees, pilot workload increased significantly. Airspeed could only be maintained within 5 knots, bank angle within 4 degrees, and pitch attitude within 5 degrees at both trim airspeeds during execution of the maneuvering stability tests (figs. 34 and 35). The longitudinal cyclic control force never became a push force, however, the reduction of the pull force was perceivable and the reduced control force cues degraded the UH-60A's flying qualities. Maneuvering stability characteristics at load factors above 1.4 will become more significant with the advent of helicopter air-to-air missions and various evasive maneuvers. Effectiveness of the UH-60A to perform these missions will be limited due to the degraded maneuvering stability characteristics above 1.4 g's. The maneuvering stability of the UH-60A failed to meet the requirements of paragraphs 10.3.3.1.4 and 10.3.3.1.4.1 of the PIDS in that the UH-60A does not exhibit positive stick-fixed or stick-free maneuvering stability in steady turning flight.

Dynamic Stability

26. Short and long-term dynamic stability was evaluated at the conditions listed in table 1. The short-term response was simulated in all control axes by making single-axis, 1 inch pulse inputs which were held for approximately 0.5 second, and by releases from steady heading sideslips during static lateral-directional tests. The longitudinal long-term response was qualitatively evaluated during other tests and in meteorological conditions ranging from calm to moderate turbulence as defined in the Flight Information Handbook (ref 13, app A).

27. The short-term response of the aircraft with AFCS ON was heavily damped, as shown in figures 36 through 38, appendix E. Single axis disturbances in all axes were damped to one-half amplitude within one cycle. The pilot was able to correct for attitude disturbances in level flight and in hover with minimal control inputs (HQRS 2). The short-term response with AFCS ON met the requirement of the PIDS and is satisfactory.

28. The long-term response with AFCS ON was not excited by normal mission maneuvers or turbulent flight conditions. The aircraft maintained attitude (±2 deg), heading (±2 deg), and airspeed (±2 knots) during "hands off" flight for extended periods of time (over 1 minute) in light to moderate turbulence. Other than normal transient altitude fluctuations, attitude and airspeed in cruise flight required minimal or no pilot control inputs (HQRS 2). The long-term response with AFCS ON met the requirement of the PIDS and is satisfactory.

29. Lateral-directional oscillatory responses were highly damped during releases from steady-heading sideslips as indicated in

figure 39, appendix E. Flight in light to moderate turbulence also exhibited a damped lateral-directional response which required no pilot compensation. The lateral-directional gust response with AFCS ON met the requirement of the PIDS and is satisfactory.

30. Adverse/proverse yaw was imperceptible to the pilot during rapid cyclic only turns. No directional pedal input was required to bank the helicopter into a turn. The adverse/proverse yaw characteristics met the requirements of the PIDS (paras 10.3.4.1.8 and 10.3.4.1.9) and are satisfactory.

Controllability

31. Controllability tests were conducted in hover and forward flight at light and heavy gross weights at an aft cg at the conditions listed in table 1. Controllability was measured as a function of aircraft attitude displacement in a given time (control power), angular rate (control response), and angular acceleration (control sensitivity) about each aircraft axis following a control input (step) of a measured size. Following the input, an attempt was made to hold controls fixed until a maximum rate was established or until recovery was necessary. The magnitude of the inputs was varied by using an adjustable rigid control fixture.

32. Longitudinal controllability characteristics are presented in figures 40 through 42, appendix E and in table 2. Representative time histories of step inputs are presented in figures 43 through 45. The magnitude of control power and control response did not change appreciably with change in airspeed, gross weight, or direction of input. Control sensitivity increased with increased airspeed, especially above approximately 80 KCAS. At heavy weight in forward flight, the Stability Augmentation System (SAS) became saturated after inputs of greater than one inch in either direction resulting in an increase in pitch rate during the maneuver (figs. 44 and 45). However, the increased pitch rate was not noticeable or objectionable to the pilot unless the input was held for several seconds. This effect was not observed at light gross weight. Control coupling was imperceptible in the longitudinal axis. Quick and precise attitude adjustments required in high speed low level flight were easily accomplished by the pilot. The longitudinal controllability met the linearity requirements of paragraph 10.3.3.4.1 of the PIDS and is satisfactory.

33. Lateral controllability characteristics are presented in figures 46 through 48, appendix E and in table 3. Representative time histories are presented in figures 49 and 50. Control power

Table 2. Longitudinal Controllability

Average Gross Weight (lb)	Average Center of Gravity (aft FS)	Average Trim Airspeed (KCAS)	Average Density Altitude (ft)	Control Power (deg/in.)[1]		Control Response (deg/sec/in.)		Control Sensitivity (deg/sec^2/in.)	
				ND[2]	NU[3]	ND	NU	ND	NU
16,900	363.6	0	2100	5.0		8.0	8.5	17	
16,840	363.7	80	6100	5.5	5.0	7.0	7.5	18	23
16,900	363.8	143	6600		6.0	8.5	9.5	27	35
22,000	360.4	78	6000		5.5	8.0	8.0	16	
21,900	360.2	109	5900		6.0		9.0	22	26

NOTE

[1]Measured after 1 second.
[2]Aircraft nose-down.
[3]Aircraft nose-up.

Table 3. Lateral Controllability

<table>
<tr><th rowspan="2">Average Gross Weight (lb)</th><th rowspan="2">Average Center of Gravity (aft FS)</th><th rowspan="2">Average Trim Airspeed (KCAS)</th><th rowspan="2">Average Density Altitude (ft)</th><th colspan="2">Control Power (deg/in.)[1]</th><th colspan="2">Control Response (deg/sec/in.)</th><th colspan="2">Control Sensitivity (deg/sec²/in.)</th></tr>
<tr><th>LT</th><th>RT</th><th>LT</th><th>RT</th><th>LT</th><th>RT</th></tr>
<tr><td>16,660</td><td>363.6</td><td>0</td><td>2080</td><td rowspan="5">4.0</td><td>3.5</td><td>10.5</td><td>10.0</td><td colspan="2">47</td></tr>
<tr><td>16,500</td><td>363.9</td><td>80</td><td>6100</td><td>3.0</td><td rowspan="2">11.0</td><td>9.5</td><td rowspan="2">44</td><td>38</td></tr>
<tr><td>16,600</td><td>363.8</td><td>141</td><td>6300</td><td>5.0</td><td>13.5</td><td>60</td></tr>
<tr><td>21,340</td><td>360.3</td><td>77</td><td>5900</td><td>3.0</td><td rowspan="2">11.5</td><td>10.0</td><td colspan="2" rowspan="2">35</td></tr>
<tr><td>21,600</td><td>360.3</td><td>109</td><td>5900</td><td>4.0</td><td>11.0</td></tr>
</table>

NOTE:

[1]Measured after 0.5 second.

and control response generated from left inputs were independent of changes in airspeed and gross weight. Right inputs resulted in equal or lower magnitudes of control power, response, and sensitivity when compared to left inputs except at lightweight (16,600 lb) and high airspeed (141 KCAS). There was no perceptible yaw or pitch coupling with lateral inputs. Time histories of lateral step inputs depict roll rate peaking in less than 1/2 second and then decreasing in magnitude about 50 percent approximately 2 seconds after achieving maximum roll rate (figs. 49 and 50). This decrease in roll rate was not objectionable to the pilot. Precise bank angles (± 2 deg) could be quickly commanded during all phases of maneuvering flight with no tendencies to overcontrol (HQRS 3). Noted as a shortcoming in USAAEFA Report No. 77-17 (ref 10, app A), lateral controllability characteristics met the requirements of paragraphs 10.3.4.2.5 and 10.3.4.2.7 of the PIDS and were considered satisfactory during this evaluation.

34. Directional controllability is presented in figures 51 through 53, appendix E and in table 4. Representative time histories of directional step inputs are presented in figures 54 and 55. Control power decreased slightly with increased airspeed. The variation in the magnitude of control response was similar to that of control power except that at a hover maximum yaw rate was not achieved before recovery. Control sensitivity varied with direction of input at a hover but was independent of direction, airspeed, and gross weight in forward flight. Most all directional controllability was affected by an unintentional lateral control input varying from 1/4 to 3/4 inch within 1/2 second of the directional input. This characteristic has been documented in three Black Hawks (prototype, first and sixth year production) and attempts to negate this input were unsuccessful. In hover and forward flight at approximately 80 KCAS at heavy and light gross weights, the unwanted lateral input was to the right for all directional inputs. At the higher airspeeds, the lateral input was in the opposite direction to that of the directional input (figs. 54 and 55). This variation in direction of lateral input can be detected in the directional controllability results as a difference in the magnitude of control power and control response. Lateral inputs in the same direction as directional inputs tended to generate greater control effectiveness. This difference was not noticeable to the pilot. During precision hovering and low speed tasks, the pilot was able to obtain and maintain yaw attitude (± 3 degrees) with minimal pilot compensation (HQRS 3). The directional controllability characteristics met the requirements of paragraphs 10.3.4.1.4 and 10.3.4.2.5 of the PIDS and are satisfactory.

Table 4. Directional Controllability

<table>
<tr><th rowspan="2">Average Gross Weight (lb)</th><th rowspan="2">Average Center of Gravity (aft FS)</th><th rowspan="2">Average Trim Airspeed (KCAS)</th><th rowspan="2">Average Density Altitude (ft)</th><th colspan="2">Control Power (deg/in.)[1]</th><th colspan="2">Control Response (deg/sec/in.)</th><th colspan="2">Control Sensitivity (deg/sec²/in.)</th></tr>
<tr><th>LT</th><th>RT</th><th>LT</th><th>RT</th><th>LT</th><th>RT</th></tr>
<tr><td>16,300</td><td>363.6</td><td>0</td><td>2100</td><td rowspan="3">6.0</td><td>7.0</td><td colspan="2">20.0[2]</td><td>25</td><td>30</td></tr>
<tr><td>16,200</td><td>364.0</td><td>79</td><td>6100</td><td>6.5</td><td rowspan="2">11.0</td><td>15.0</td><td colspan="2" rowspan="2">28</td></tr>
<tr><td>16,300</td><td>363.9</td><td>142</td><td>6400</td><td>6.0</td><td>11.5</td></tr>
<tr><td>21,000</td><td>360.4</td><td>77</td><td>5900</td><td>5.0</td><td>6.0</td><td>10.0</td><td>13.5</td><td rowspan="2">28</td><td rowspan="2">29</td></tr>
<tr><td>21,260</td><td>360.3</td><td>110</td><td>6000</td><td colspan="2">5.0</td><td colspan="2">10.0</td></tr>
</table>

NOTES:

[1]Measured after 1 second.
[2]Yaw rate at 1.5 seconds.

Low Speed Flight Characteristics

35. The low speed flight characteristics of the UH-60A were evaluated at the conditions in table 1 to determine control margins and handling qualities. Testing was performed at speeds up to approximately 35 KTAS in rearward and right sideward flight utilizing a ground pace vehicle as a speed reference. The helicopter was flown in-ground effect at a wheel height of approximately 25 feet. The low speed flight test data are presented in figures 56 and 57, appendix E.

36. The variation of lateral cyclic control position during right sideward flight was conventional (increasing right lateral cyclic control with increasing right sideward airspeed). As the right sideward flight speed was increased, more forward longitudinal cyclic control was required. There was a total change of 1.5 inches of longitudinal cyclic control over the speed range tested. Adequate margins remained for all flight controls. Flight control trends were nearly linear and only minimal pilot compensation was required to maintain heading within ± 1 degree. The low speed flight characteristics in right sideward flight remained essentially unchanged from previous evaluations and are satisfactory.

37. During rearward flight, the UH-60A exhibited a slightly positive control position gradient (increasing aft longitudinal cyclic control with increasing rearward airspeed). This shallow gradient, which resulted in limited flight control position and force cues, did not adversely effect the pilot's ability to control the helicopter because of adequate outside visual cues. As rearward airspeed increased, lateral cyclic control changes of nearly 2 inches were required. Adequate control margins remained in all flight controls, however, density altitude was only 2180 feet. The low speed flight characteristics in rearward flight remained essentially unchanged from previous evaluations and are satisfactory.

Aircraft System Failure

38. Aircraft system failures were investigated at the conditions in table 1. Simulated failures of the No. 1 engine and simulated hardovers of the No. 1 and No. 2 SAS, Flight Path Stabilization (FPS), PBA, and stabilator systems were conducted.

Simulated Engine Failures:

39. Sudden single engine failure from dual engine flight was simulated by rapidly retarding the No. 1 engine power control lever to the idle stop. The aircraft response was evaluated

during level flight at lightweight/aft cg (approximately 16,300 lb/365.6 inches) at airspeeds of 75 and 143 KCAS. Flight controls were held fixed following the power loss for approximately 2 seconds or until excessive aircraft angular rates were reached. Representative time histories of simulated single engine failures are presented in figures 58 and 59, appendix E.

40. Aircraft response to a sudden single-engine failure from stabilized dual-engine level flight was mild. At 143 KCAS (fig. 58, app E) the primary reaction of the aircraft was a 4 degree left yaw, a 5 degree left roll, and a very slight nose-down pitch. The primary cockpit indications of a single-engine failure were reduction of power turbine speed into the red zone, reduction of torque, and rotor droop below 95 percent rpm activating the aural warning system. At this airspeed, pilot cues were adequate for timely corrective action. No unusual or rapid control application was necessary except an 8 percent reduction in collective was required after rotor speed decayed below the warning limit value of 95 percent. The aircraft reaction at 75 KCAS (fig. 59) was a slight perturbation in pitch, roll, yaw, and rotor speed with no collective reduction required. At lower airspeed/power settings, the response cues were very mild and the engine out aural warning system (activated at 55 percent engine gas generator speed) would be the major cue of engine failure. The single-engine failure characteristics from dual-engine flight are satisfactory.

Automatic Flight Control System Failures:

41. Single axis SAS hardovers in all axes and nose-up PBA hardovers were conducted in forward flight at 75 and 145 knots indicated airspeed (KIAS) on the ship airspeed system at light weight/aft cg. No. 1 and No. 2 SAS hardovers in all three axes resulted in mild attitude changes which were easily compensated for by the pilot. Hardover failure in the longitudinal axis resulted in a maximum pitch attitude change of 15 degrees nose-up in approximately 3 seconds at 145 KIAS. In the roll axis, SAS hardovers resulted in maximum roll rates of approximately 5 degrees/second generating stabilized bank angles of 10 to 15 degrees. Directional hardovers caused heading changes of 2 degrees (at 75 KIAS) to 4 degrees (at 145 KIAS). No perceivable differences in handling characteristics were noted between failures of the No. 1 and No. 2 SAS systems. Nose-up failure of the PBA resulted in illumination of the PITCH BIAS FAIL caution light in conjunction with a very mild pitch attitude change of approximately 5 degrees. The single axis hardover characteristics of the SAS and PBA systems met the requirements of the PIDS and are satisfactory.

42. The FPS system failures were evaluated at 75 and 145 KIAS in level flight by switching off the FPS switch on the AFCS panel. In addition, the FPS system was evaluated in conjunction with other handling qualities tests. The disengagement of the FPS switch resulted in illumination of the MASTER CAUTION, FLT PATH STAB, and TRIM FAIL caution lights in addition to loss of attitude and airspeed hold functions. No unusual attitude change or rate buildup occurred subsequent to FPS failure and met the requirement of the PIDS. However, during controllability tests it was noted that forward longitudinal inputs greater than 1/2 inch consistently caused failure of the FPS system which required resetting the MASTER CAUTION, FPS, and TRIM switches. This characteristic would cause failure of the FPS system during nap-of-the-earth and maneuvering flight and is an annoying distraction which will increase crew workload. The consistent failure of the FPS during forward longitudinal inputs greater than 1/2 inch is a shortcoming. The above shortcoming appears similar to the shortcoming previously reported in USAAEFA Report No. 77-17 (ref 10, app A).

43. Stabilator TE up (TEUP) hardover failures were tested in level flight at 75 and 145 KIAS. The failure was conducted through the hardover box installed in the AFCS system and resulted in the stabilator moving nearly 5 degrees TEUP within 2 seconds. Following the hardover, an attempt was made to hold controls fixed. A representative time history is presented in figure 60, appendix E. At 145 KIAS, stabilator TEUP hardover failures resulted in a moderate nose-up pitch of approximately 10 degrees from trim with a maximum nose-up pitch rate of about 3 degrees/second. Ten seconds after the failure was initiated, airspeed decayed approximately 12 knots and the aircraft gained 200 ft in altitude. At 70 KIAS, the aircraft reaction was slightly more mild. The relatively mild reactions of the aircraft within the airspeed range tested to a TEUP stabilator hardover would be easily recognized by the pilot and require minimal compensation to maintain desired airspeed and altitude (HQRS 3). The stabilator TEUP hardover characteristics are satisfactory.

VIBRATION CHARACTERISTICS

44. Vibration characteristics were qualitatively evaluated throughout the test program and quantitatively evaluated at the conditions listed in table 1. Vibration accelerometers were installed at the aircraft cg, the pilot's seat, and the pilot's floor (app C). Main rotor harmonics of 1/rev, 4/rev and 8/rev are presented in figures 61 through 72, appendix E.

45. The 1/rev vibratory accelerations were similar at all the stations and all axes. Neither change in gross weight nor cg

location changed the amplitude of the 1/rev vibratory accelerations significantly. The highest 1/rev vibratory accelerations (.02 to .03 g's) were generally observed in the vertical and lateral axes. The 1/rev vibration characteristics met the PID requirements and are satisfactory.

46. The 4/rev lateral vibratory accelerations measured at the pilot seat were highest (approximately 0.2 to 0.4 g) at airspeeds less than 80 KCAS in the aft cg configurations. The lateral 4/rev vibratory accelerations measured at the pilot's floor increased in amplitude (approximately 0.15 to 0.30 g) as did the pilot seat at similar test conditions. The 4/rev vibration characteristics appeared independent of change in gross weight. Both the pilot's seat and floor lateral vibration characteristics failed to meet the requirements of paragraph 3.2.1.1.3.1.4 of the PIDS in that the amplitudes were greater than 0.15 g. Generally, the 4/rev vibratory accelerations measured at the floor near the aircraft cg were lower than those measured at the other two locations. The highest amplitudes (approximately 0.15 to 0.30 g) were usually at airspeeds near 45 KCAS in the vertical and longitudinal axes. The vertical and longitudinal cg vibration characteristics failed to meet the requirements of paragraph 3.2.1.1.3.1.4 of the PIDS in that the amplitudes were greater than 0.15 g's at 45 KCAS. The 4/rev vibration characteristics were aggravated by aft movement of the cg. The excessive 4/rev vibrations remain a shortcoming that should have a high priority for correction and have been documented in several previous USAAEFA reports.

47. The 8/rev vibratory accelerations were generally independent of changes in gross weight and cg. The pilot seat 8/rev vibratory characteristics were increased in amplitude when compared to the other two floor locations, especially in the lateral axis. Amplitudes up to 0.34 g, the specification limit, were measured in the lateral axis at 45 KCAS. The 8/rev vibration characteristics met the PIDS requirements and are satisfactory.

AIRSPEED CALIBRATION

48. The standard ship airspeed system incorporated changes developed during USAAEFA Project No. 82-09 (ref 3, app A) and is similar to the current production system. Calibrations generated during USAAEFA Project No. 82-09 were verified through use of a calibrated T-28 pace aircraft and a calibrated trailing bomb, and subsequently used as a basis in this evaluation. A normalized curve of the forward and aft cg calibrations depicting ship airspeed system position error in level flight was generated and is presented in figure 73, appendix E.

CONCLUSIONS

GENERAL

49. Based on this evaluation, the following conclusions were reached about the expanded gross weight and center of gravity (cg) envelope of the UH-60A in the normal utility configuration.

a. Equivalent flat plate area was minimum with the cg at fuselage station (FS) of approximately 360 and increased at a more forward and aft cg tested (FS 347.1 and [illegible].7).

b. Generally, 4-per-rotor-revolution (4/rev) vibration characteristics were unaffected by increasing gross weight but were aggravated by moving the longitudinal cg aft.

c. One deficiency, three shortcomings and three specification noncompliances were noted, of which, one shortcoming was associated with envelope expansion, and one previously noted shortcoming was made worse due to envelope expansion.

d. Except for the shortcoming pertaining to neutral stick-fixed longitudinal stability in intermediate rated power (IRP) climb, the handling qualities were essentially unchanged from those previously reported.

DEFICIENCY

50. The uncommanded directional control input in trimmed forward flight is a deficiency, unrelated to the expanded gross weight and cg envelope, that was identified during a previous evaluation and still exists (para 12).

SHORTCOMINGS

51. The following shortcomings were identified and are listed in decreasing order of importance.

a. The excessive 4/rev vibrations during certain flight conditions (para 46).* #

b. The neutral stick-fixed static longitudinal stability in a light gross weight and aft cg configuration at IRP in climb (para 15). #

*Reported during previous evaluation
#Associated with envelope expansion

c. The consistent failure of the flight path stabilization system during longitudinal inputs greater than 1/2 inch (para 42).*

SPECIFICATION NONCOMPLIANCES

52. The UH-60A helicopter failed to meet the following requirements of the PIDS.

a. Paragraph 3.2.1.1.3.1.4 - The 4/rev vibration levels during certain flight conditions exceeded the requirements of this paragraph (para 46).*

b. Paragraph 10.3.3.1.3 - The longitudinal static stability is neutral instead of positive at 144 KCAS in level flight and in IRP climbs at light gross weight and aft cg (paras 14 and 15).#

c. Paragraph 10.3.3.1.4 - The maneuvering stability is not positive stick-fixed or stick-free at all bank angles during steady turning flight (para 25).*

*Reported during previous evaluation
#Associated with envelope expansion

RECOMMENDATION

53. The deficiency and shortcomings reported in paragraphs 50 and 51 should be corrected.

APPENDIX A. REFERENCES

1. Letter, AVRADCOM, DRDAV-D, 6 October 1981, subject: UH-60A Expanded Gross Weight and Center of Gravity Evaluation, USAAEFA Project No. 81-16.

2. Prime Item Development Specification, Sikorsky Aircraft Division, *DARCOM-CP-2222-51000D Part 1*, 15 October 1979.

3. Final Report, USAAEFA Project No. 82-09, *Preliminary Airworthiness Evaluation of the UH-60A with an Improved Airspeed System*, April 1983.

4. Technical Manual, TM55-1520-237-10, *Operator's Manual, UH-60A Helicopter*, Headquarters, Department of the Army, 21 May 1979, with change 21 dated 12 August 1983.

5. Letter, AVRADCOM, DRDAV-L June 1983, subject: Airworthiness Release for UH-60A Black Hawk Helicopter, S/N 77-22716, to Conduct Expanded Gross Weight and Center of Gravity Testing, USAAEFA Project No. 81-16.

6. Letter, USAAEFA, DAVTE-TB, 25 March 1982, subject: Test Plan, UH-60A Expanded Gross Weight and Center of Gravity Evaluation, USAAEFA Project No. 81-16.

7. Engineering Design Handbook, Army Materiel Command, AMC Pamphlet 706-204, *Helicopter Performance Testing*, 2 August 1974.

8. Flight Test Manual, Naval Air Test Center, FTM No. 101, *Stability and Control*, 10 June 1968.

9. Final Report, USAAEFA Project No. 83-24, *Airworthiness and Flight Characteristics Test of a Sixth Year Production UH-60A*, June 1985 (unpublished).

10. Final Report, USAAEFA Project No. 77-17, *Airworthiness and Flight Characteristics Evaluation UH-60A (Black Hawk) Helicopter*, September 1981.

11. Letter, USAAEFA Project No. 78-22, 26 April 1979, subject: Preliminary Airworthiness Evaluation (PAE III, UH-60A Black Hawk Helicopter).

12. Final Report, USAAEFA Project No. 82-15, *Airworthiness and Flight Characteristics Test of the UH-60A Configured with the Prototype External Stores Support System (ESSS)*, December 1983.

13. Flight Information Publication. Defense Mapping Agency Aerospace Center, Flight Information Handbook, 4 July 1984.

14. Technical Manual, TM55-1520-237-23-2, *Aircraft General Information Manual, UH-60A Helicopter* Headquarters Department of the Army, 29 December 1978.

APPENDIX B. AIRCRAFT DESCRIPTION

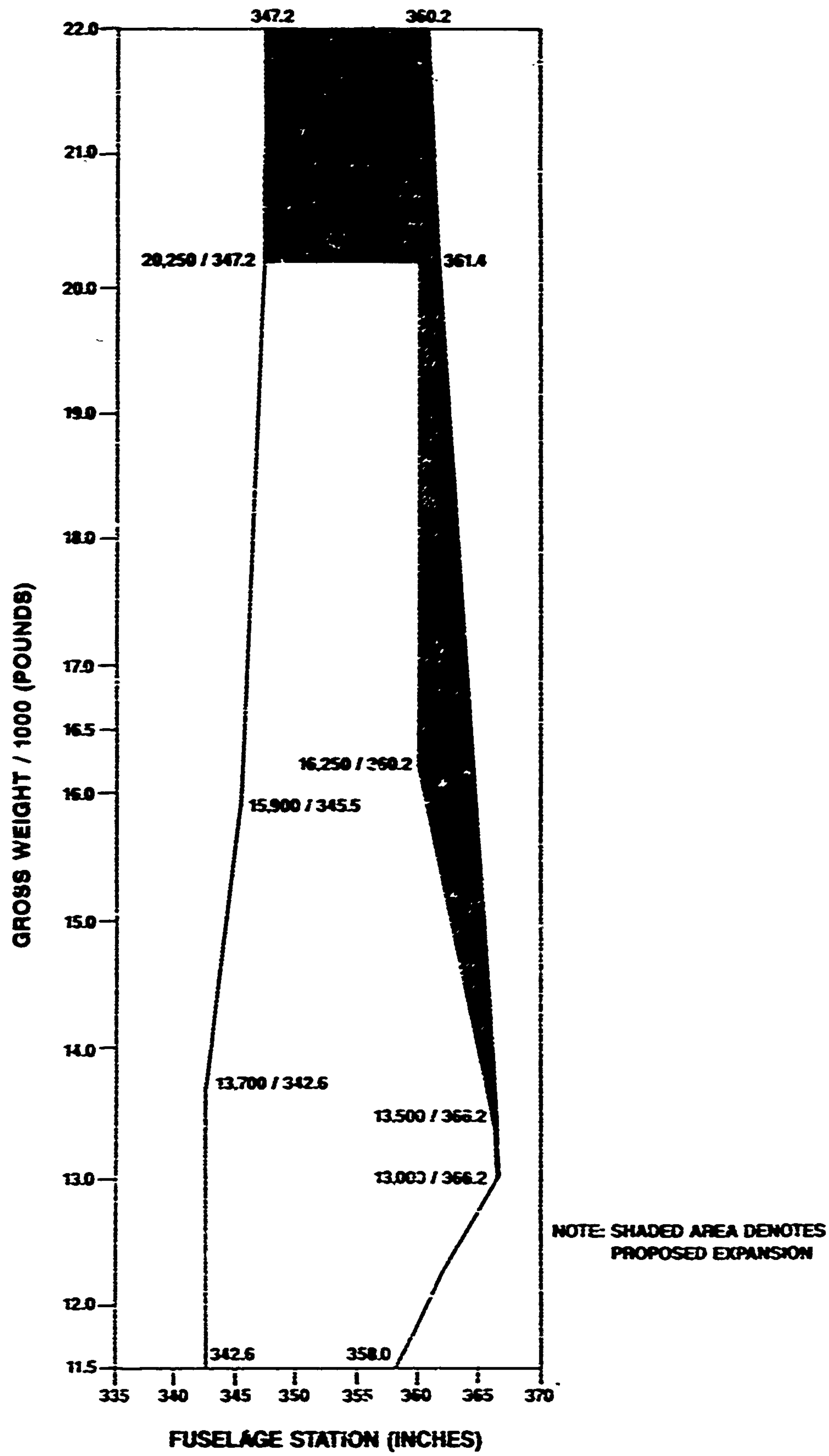
GENERAL

1. The Sikorsky UH-60A (Black Hawk) is a twin turbine engine, single main rotor helicopter capable of transporting 11 combat troops plus a crew of three. It is equipped with 3 nonretractable conventional wheel-type landing gear. A movable horizontal stabilator is located on the lower portion of the tail rotor pylon. The main and tail rotors are both four-bladed with a capability of manual main rotor blade and tail pylon folding. The cross-beam tail rotor with composite blades is attached to the right side of the pylon and is canted 20 degrees upward from the horizontal. A complete description of the aircraft is contained in the operator's manual (ref 4, app A) and the aircraft general information manual (ref 14). The proposed expansion of the gross weight and center of gravity envelope is shown in figure 1.

ENGINES

2. The primary power plants for the UH-60A helicopter are General Electric T700-GE-700 front drive turboshaft engines, each rated at 1553 shaft horsepower (SHP) (30 minute limit) at a power turbine speed of 20,900 revolutions per minute (rpm) (sea level, standard day installed). The engines are mounted in nacelles on either side of the main transmission. Each engine has four modules: cold section, hot section, power turbine section, and accessory section. Design features include an axial-centrifugal flow compressor, a through-flow combustor, a two-stage uncooled high pressure gas generator turbine, a two-stage uncooled power turbine, and self contained lubrication and electrical systems. Pertinent engine data are shown below.

Model	T700-GE-700
Type	Turboshaft
Rated power	1553 SHP installed at sea level, standard-day static conditions at 20,900 rpm
Compressor	Five axial stages, 1 centrifugal stage
Combustion chamber	Single annular chamber with axial flow
Gas generator stages	2
Power turbine stages	2
Direction of engine rotation (aft looking fwd)	Clockwise
Weight (dry)	415 pounds max
Length	47 in.
Maximum diameter	25 in.
Fuel	MIL-T-5624 grade JP-4 or JP-5


347.2
360.2
22.0
21.0
20,250 / 347.2
361.4
20.0
19.0
18.0
17.0
16.5
16,250 / 360.2
16.0
15,900 / 345.5
15.0
14.0
13,700 / 342.6
13,500 / 366.2
13.0
13,000 / 366.2
12.0
342.6
358.0
11.5
335
340
345
350
355
360
365
370
GROSS WEIGHT / 1000 (POUNDS)
FUSELAGE STATION (INCHES)
NOTE: SHADED AREA DENOTES PROPOSED EXPANSION

BASIC AIRCRAFT INFORMATION

3. General data of the UH-60A helicopter are as follows:

Gross Weight

Maximum alternate gross weight*	20,250 pounds
Empty weight	Approximately 10,620 pounds
Primary Mission gross weight	16,260 pounds
Fuel capacity (measured)	360 gallons

*See figure 1 for current and proposed gross weight and center of gravity information

Main Rotor

Number of blades	4
Diameter	53 ft, 8 in.
Blade chord	1.73/1.75 ft
Blade twist	-18 deg (equivalen
Blade tip sweep	20 deg aft
Blade area (one blade)	46.7 sq ft
Airfoil	
section (root to tip designation)	SC1095/SC1095R8
thickness (percent chord)	9.5 percent
Main rotor mast tilt (forward)	3 deg

Tail Rotor

Number of blades	4
Diameter	11 ft
Blade chord	0.81 ft
Blade twist (equivalent linear)	-18 deg

Blade area (one blade)	4.46 sq ft
Airfoil	
section (root to tip designation)	SC1095/SC1095R8
thickness (percent chord)	9.5 percent
Cant angle	20 deg

Gear Ratios

Main Transmission	Input RPM	Output RPM	Ratio	(Teeth)
Input bevel	20,900.0	5747.5	3.6364	(80/22)
Main bevel	5747.5	1206.3	4.7647	(81/17)
Planetary	1206.3	257.9	4.6774	$\frac{(228 + 62)}{62}$
Tail takeoff	1206.3	4115.5	0.2931	(34/116)
Accessory bevel (generator)	5747.5	11,805.7	0.4868	(37/76)
Accessory spur (hydraulics)	11,805.7	7186.1	1.6429	(92/56)
Intermediate Gearbox	4115.5	3318.9	1.2400	(31/25)
Tail Gearbox	3318.9	1189.8	2.7895	(53/19)
Overall				
Engine to main rotor	20,900.0	257.9	81.0419	
Engine to tail rotor	20,900.0	1189.8	17.5658	
Tail rotor to main rotor	1189.8	257.9	4.6136	

AIRSPEED/STABILATOR MODIFICATIONS

4. The airspeed/stabilator system on the test aircraft included five modifications from the original production aircraft in an attempt to eliminate pitch oscillations during takeoff, improve climb handling qualities, and reduce large position error during various airspeed regimes. Three changes were incorporated in the pitot-static pressure systems and two changes were electrical circuit modifications to the stabilator amplifiers in the stabilator system. Major features of this system are described in

detail in the Preliminary Airworthiness Evaluation of UH-60A with an Improved Airspeed System, USAAEFA Report No. 82-09, (ref 3, app A).

APPENDIX C. INSTRUMENTATION

GENERAL

1. The test instrumentation was installed, calibrated and maintained by the US Army Aviation Engineering Flight Activity personnel. A test airspeed boom with swiveling pitot-static head connected to an airspeed indicator and altimeter were installed at the nose of the aircraft. Equipment required only for specific tests was installed when needed and is discussed in the section on special equipment. Data was obtained from calibrated instrumentation and displayed or recorded as indicated below.

Pilot Position

Airspeed (boom system)
Altitude (boom system)
Altitude (radar-dual range)*
Rate of climb*
Rotor speed (sensitive)
Engine torque* **
Turbine gas temperature ($T_{4.5}$)* **
Engine gas generator speed * **
Control positions
    Longitudinal
    Lateral
    Pedal
    Collective
Stabilator position
Angle of sideslip
Center of gravity normal acceleration
Sensitive bank angle (center of gravity lateral acceleration)
Event switch

Copilot/Engineer Station

Airspeed (ship's system)
Altitude (ship's system)
Rotor speed*
Engine torque* **
Total air temperature
Fuel used (totalizer)
Ballast cart position

*Ship's system/not calibrated
**Both engines

Time code display
Run number
Event switch

Digital (PCM) Data Parameters

Airspeed (ship's system)
Airspeed (boom system)
Altitude (boom system)
Altitude (ship's system)
Altitude (radar)
Total air temperature
Rotor speed
Engine torque**
Turbine gas temperatures ($T_{4.5}$)**
Engine gas generator speed**
Engine power turbine speed**
Engine fuel flow**
Engine fuel used**
Engine fuel temperature (at fuel used transducer)**
Auxiliary Power Unit (APU) fuel used
APU fuel temperature (at fuel used transducer)
Main rotor shaft torque (3)
Main rotor shaft bending (2)
Tail rotor shaft torque
Tail rotor impress pitch
Stabilator position
Ballast cart position
Control positions
- Longitudinal
- Lateral
- Pedal
- Collective

Power available spindle position**
Stability augmentation system output position
- Longitudinal
- Lateral
- Directional

Control mixer input position
- Longitudinal
- Lateral
- Directional

Angle of attack
Angle of sideslip

**Both engines

Aircraft attitude
- Pitch
- Roll
- Yaw

Aircraft angular rate
- Pitch
- Roll
- Yaw

Linear acceleration
- Center of gravity normal
- Center of gravity lateral
- Center of gravity longitudinal

Time of day

Run number

Data status words

Pilot event

Engineer event

Analog (FM) Data Parameters

Vibration
- Pilot seat vertical
- Pilot seat lateral
- Pilot seat longitudinal
- Center of gravity vertical
- Center of gravity lateral
- Center of gravity longitudinal
- Pilot floor vertical
- Pilot floor lateral

Loads
- Main rotor longitudinal star load

2. Provision was made for telemetry transmission of parameters.

AIRSPEED CALIBRATION

3. The standard ship airspeed system and test boom airspeed system were calibrated previously during USAAEFA Project No. 82-09 (ref 3, app A) in level flight, climb, and autorotation. A check of these calibrations was performed utilizing a calibrated T-28 pace aircraft and a calibrated trailing bomb (finned pitot-static system). The resultant curves depicting position error of the boom airspeed system are presented in figures 1 and 2.

FIGURE 1
BOOM SYSTEM AIRSPEED CALIBRATION IN LEVEL FLIGHT
UH-60A USA S/N 77-22716

NOTE: BASIS FOR CURVE IS USAAEFA REPORT NO. 82-09, REFINED FOR THIS PROJECT

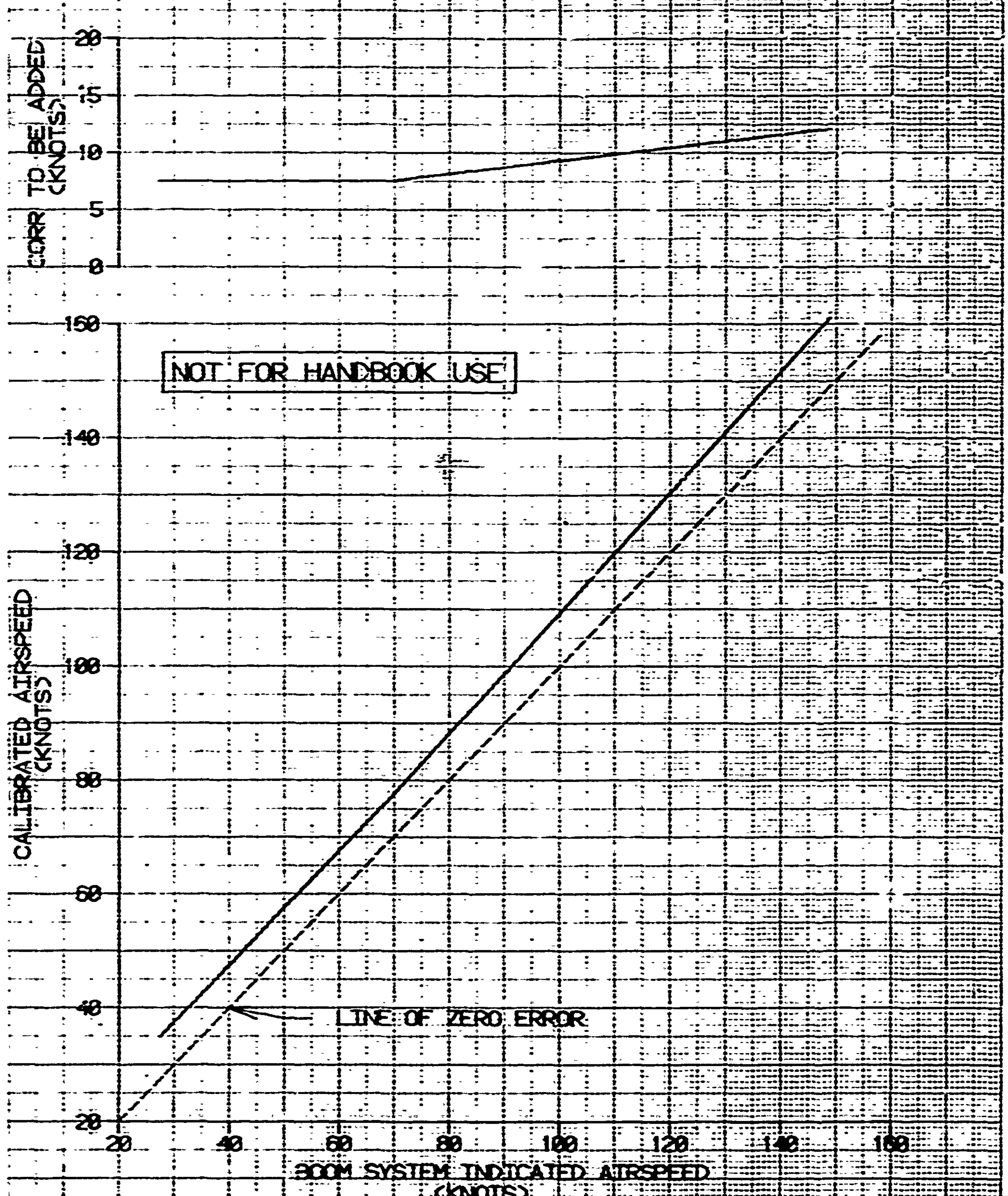
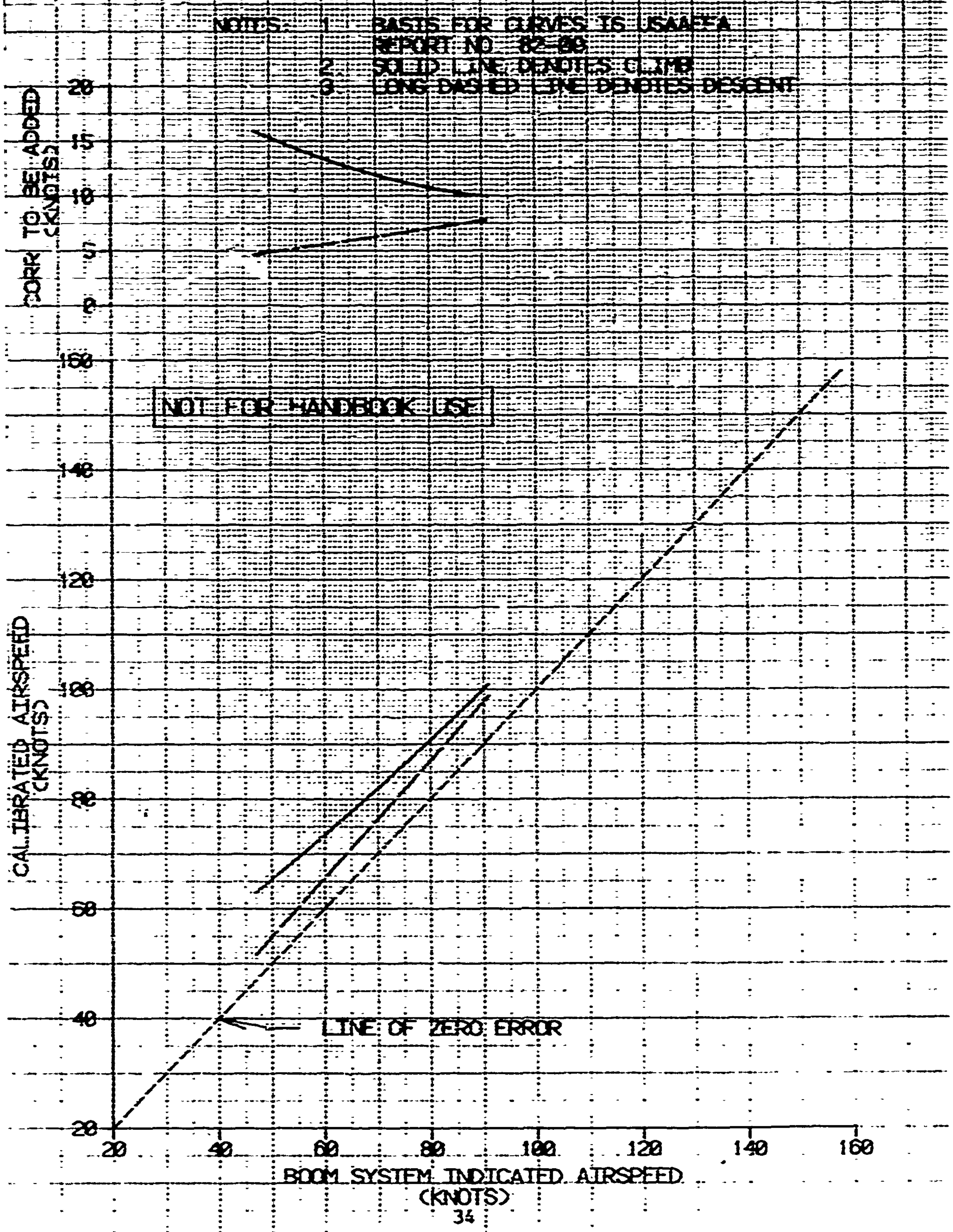


FIGURE 2
BOOM SYSTEM AIRSPEED CALIBRATION IN CLIMBING AND DESCENDING FLIGHT
UH-60A USA S/N 77-22716



SPECIAL EQUIPMENT

Control Fixtures

4. Cyclic and pedal mechanical fixtures were utilized at the copilot station to obtain a desired control input size about the longitudinal, lateral, and directional axes at the pilot station.

Ground Pace Vehicle

5. A vehicle utilizing a calibrated fifth wheel to determine accurate ground speed was used in conjunction with wind speed and direction to provide a precise airspeed reference for the test aircraft during low speed tests.

Weather Station

6. A portable weather station, consisting of an anemometer, sensitive temperature gage, and barometer, was used to record wind speed, wind direction, ambient temperature, and pressure altitude during low speed tests.

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

GENERAL

1. Performance data were obtained using the basic methods described in Army Materiel Command Pamphlet AMCP 706-204 (ref 7, app A). Performance testing was conducted in coordinated (ball-centered) flight. Handling qualities data were evaluated using standard test methods described in Naval Air Test Center Flight Test Manual FTM No. 101 (ref 8).

AIRCRAFT RIGGING

2. A flight controls engineering rigging check was performed on the main and tail rotors to insure compliance with established limits and representative handling qualities information. The stabilator control system was adjusted to conform as close as possible to the modified production schedule to prevent improper drag characteristics affecting level flight performance.

AIRCRAFT WEIGHT AND BALANCE

3. The aircraft was weighed in the instrumented configuration with full oil and all fuel drained prior to the start of the program. The initial weight of the aircraft was 11,989 pounds with the longitudinal center of gravity (cg) located at FS 351.9 with the cg of the empty ballast cart located at FS 391. In addition, the aircraft was weighed when configured for a test condition outside the then existing flight envelope. The fuel cells and an external sight gage were also calibrated. The measured fuel capacity using the gravity fueling method was 360 gallons. The fuel weight for each test flight was determined prior to engine start and after engine shutdown by using the external sight gage to determine the volume and measuring the specific gravity of the fuel. The calibrated cockpit fuel totalizer indicator was used during the test and at the end of each test was compared with the sight gage readings. Aircraft cg was controlled by a moveable ballast system which was manually positioned to maintain a constant cg while fuel was burned. The moveable ballast system was a cart (2000-pound capacity) attached to the cabin floor by rails and driven by an electric screw jack with a total longitudinal travel of 72.3 inches.

PERFORMANCE

4. Helicopter performance was generalized through the use of nondimensional coefficients as follows using the 1968 US Standard Atmosphere:

a. Coefficient of Power (C_P):

$$C_P = \frac{SHP\ (550)}{\rho A(\Omega R)^3} \tag{1}$$

b. Coefficient of Thrust (C_T):

$$C_T = \frac{GW}{\rho A(\Omega R)^2} \tag{2}$$

c. Advance Ratio (μ):

$$\mu = \frac{V_T\ (1.6878)}{\Omega R} \tag{3}$$

Where:

SHP = Engine output shaft horsepower (both)

ρ = Ambient air density ($lb\text{-}sec^2/ft^4$)

A = Main rotor disc area = 2262 ft^2

Ω = Main rotor angular velocity (radians/sec)

R = Main rotor radius = 26.833 ft

GW = Gross weight (lb)

V_T = True airspeed (kt) = $\dfrac{V_E}{1.6878\sqrt{\rho/\rho_o}}$

1.6878 = Conversion factor (ft/sec-kt)

ρ_o = 0.0023769 ($lb\text{-}sec^2/ft^4$)

V_E = Equivalent airspeed (ft/sec) =

$$\left\{ \frac{7(70.7262\ P_a)}{\rho_o} \left[\left(\frac{Q_c}{P_a} + 1 \right)^{2/7} - 1 \right] \right\}^{1/2}$$

70.7262 = Conversion factor (lb/ft^2-in.-Hg)

Q_c = Dynamic pressure (in.-Hg)

P_a = Ambient air pressure (in.-Hg)

100% rotor speed = 257.9 revolutions per minute (rpm)

ΩR = 724.69

$(\Omega R)^2$ = 525,168.15

$(\Omega R)^3$ = 380,581,411.2

5. The engine output shaft torque was determined by use of the engine torque sensor. The power turbine shaft contains a torque sensor tube that mechanically displays the total twist of the shaft. A concentric reference shaft is secured by a pin at the front end of the power turbine drive shaft and is free to rotate relative to the power turbine drive shaft at the rear end. The relative rotation is due to transmitted torque, and the resulting phase angle between the reference teeth on the two shafts is picked up by the torque sensor. The torque sensor on both engines was calibrated in a test cell by the engine manufacturer. The output from the engine sensor was recorded on the on-board data recording system. The output SHP was determined from the engine's output shaft torque and rotational speed by the following equation.

$$SHP = \frac{Q(N_P)}{5252.113} \qquad (4)$$

Where:

Q = Engine output shaft torque (ft-lb)

N_P = Engine output shaft rotational speed (rpm)

5252.113 = Conversion factor (ft-lb-rev/min-SHP)

The output SHP required was assumed to include 13 horsepower for daylight operations of the aircraft electrical system, but was corrected for the effects of test instrumentation installation. A power loss of 1.82 horsepower was determined for electrical operation of the instrumentation. Reductions in power required were made for the effect of external instrumentation drag. This was determined by the following equation.

$$SHP_{instr\ drag} = \frac{F_e\ (\rho/\rho_o)(V_T)^3}{96254} \qquad (5)$$

Where:

$F_e = 0.833\ ft^2$ (estimated)

96254 = Conversion factor (ft^2-kt^3/SHP)

6. Each speed power was flown in ball-centered flight by reference to a sensitive lateral accelerometer at a predetermined C_T and referred rotor speed ($N_R/\sqrt{\theta}$). To maintain the ratio of gross weight to pressure ratio constant, altitude was increased as fuel was consumed. To maintain $N_R/\sqrt{\theta}$ constant, rotor speed was decreased as temperature decreased. Power corrections for rate-of-climb and acceleration were determined (when applicable) by the following equations.

$$SHP_{R/C} = -\frac{(R/C_{TL})(GW)}{33{,}000(K_P)} \qquad (6)$$

$$SHP_{ACCEL} = -1.6698 \times 10^{-4} \left(\frac{\Delta V}{\Delta t}\right) (V_T)\ (GW) \qquad (7)$$

Where:

R/C_{TL} = Tapeline rate of climb (ft/min) = $\left(\frac{\Delta H_P}{\Delta t}\right)\left(\frac{OAT + 273.15}{OAT_S + 273.15}\right)$

$\frac{\Delta H_P}{\Delta t}$ = Change in pressure altitude per unit time (ft/min)

OAT_S = Standard ambient temperature at pressure altitude where $\frac{\Delta H_P}{\Delta t}$ was measured (°C)

$K_p = 0.76$

1.6098×10^{-4} = Conversion factor (SHP-sec/kt^2-lb)

$\frac{\Delta V}{\Delta t}$ = Change in airspeed per unit time (kt/sec)

A power correction to insure ball-centered test data complied with the inherent sideslip family of curves depicting the UH-60A in figures 16 and 17, appendix E, was determined from ΔF_e as a function of sideslip angle (fig. 20) and equation 5 rewritten as follows.

$$SHP_{s/s} = \frac{(\Delta F_{e\ in\ s/s} - \Delta F_{e\ B-C})\ (\rho/\rho_o)\ (V_T^3)}{96254} \qquad (8)$$

Where:

$\Delta F_e{}^*{}_{in\ s/s}$ = Change in equivalent flat plate area based on UH-60A inherent sideslip.

$\Delta F_e{}^*{}_{B-C}$ = Change in equivalent flat plate area based on the sideslip angle measured in ball-centered flight.

*Based on change in engine shaft horsepower.

Power required for level flight at the test day conditions was determined using the following equation.

$$SHP_t = SHP + SHP_{R/C} + SHP_{ACCEL} + SHP_{s/s} - SHP_{instr\ drag} - 1.82 \qquad (9)$$

7. Test day level flight data was corrected to average test day conditions by the following equations.

$$SHP_s = SHP_t \frac{(\delta_s \sqrt{\theta_s}) \left[\frac{N_R}{\sqrt{\theta}}\right]_s^3}{(\delta_t \sqrt{\theta_t}) \left[\frac{N_R}{\sqrt{\theta}}\right]_t^3} \qquad (10)$$

$$V_{T_s} = V_{T_t} \frac{\left[\frac{N_R}{\sqrt{\theta}}\right]_s}{\left[\frac{N_R}{\sqrt{\theta}}\right]_t} \quad (11)$$

Where:

N_R = Main rotor speed (rpm)

subscript t = Test day

subscript s = Average test day

Test data corrected for rate of climb, acceleration, instrumentation installation, and corrected to inherent sideslip, standard altitude, and ambient temperature are presented in figures 4 through 15, appendix E.

8. Level flight performance was determined by subtracting the difference in power required at $N_R/\sqrt{\theta} = 258$ rpm noted in USAAEFA Report No. 83-24 (ref 9, app A) between the first and sixth year production aircraft in their respective normal utility configurations. Values of C_P of the sixth year UH-60A were extracted from the family of curves of C_P versus $N_R/\sqrt{\theta}$ for lines of constant C_T at increments of μ (ref 9) at the average C_T and $N_R/\sqrt{\theta}$ conditions of the flights conducted during this evaluation. Power required in level flight was obtained as follows.

$$C_P = C_{P_{6th\ yr\ A/C}} - \Delta C_P \quad (12)$$

Where:

$$\Delta C_P = \frac{\Delta F_e \mu^3}{2A} \quad (13)$$

$\Delta F_e = 5\ ft^2$ (change in equivalent flat plate area between the first and sixth year normal utility configured UH-60A helicopters; ESSS fairings ($2.5\ ft^2$), M-130 and AN/ALQ-144(V) brackets ($1.5\ ft^2$), external drag differences ($1\ ft^2$))

Results of the sixth year production UH-60A carpet plot converted to a first year at the average $N_R/\sqrt{\theta}$ for these tests and extrapolated to a C_T of 0.011007 are presented in figures 1 through 3, appendix E. Correlation of these curves with data flown during this evaluation is depicted in figures 4 through 9.

9. Changes in the ΔF_e due to change in aircraft cg were calculated from equation 13 solved for ΔF_e. The ΔC_P is the difference in C_P as derived from the nondimensional plots at the normal utility forward cg configuration and the C_P for the cg desired.

HANDLING QUALITIES

10. Conventional test techniques were used during the conduct of the handling qualities tests. All tests were conducted in ball-centered flight. A brief description of all test techniques are presented in respective paragraphs of the Results and Discussion section and detailed descriptions are contained in reference 8, appendix A. The basis for evaluation was the Handling Qualitites Rating Scale shown in figure 1.

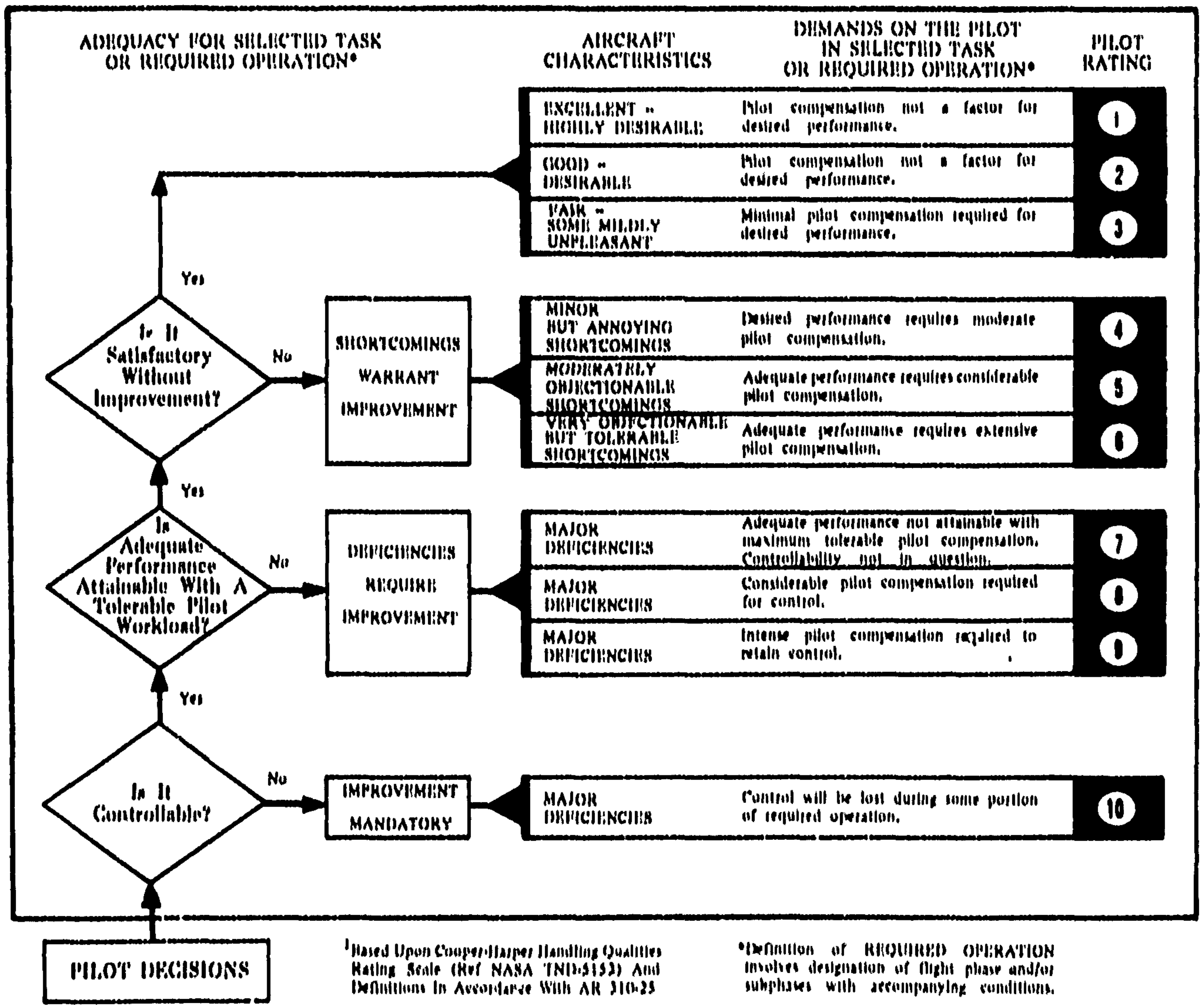
VIBRATION

11. Spectral plots of each vibration parameter were generated depicting frequencies versus single amplitude acceleration (g). The data were analyzed using a frequency range of zero to 50 Hz and frequency resolution of 0.5 Hz. In order to minimize random variation in acceleration amplitude, the data were averaged over a 20-second time interval. An analysis of the main rotor fundamental frequency and it's second, fourth, and eighth harmonics was made. The second harmonic vibratory accelerations were insignificant in comparison to the fourth and eighth harmonics and, therefore, not presented.

DEFINITIONS

12. Results were categorized as deficiencies or shortcomings in accordance with the following definitions.

<u>Deficiency</u>: A defect or malfunction discovered during the life cycle of an item of equipment that constitutes a safety hazard to personnel; will result in serious damage to the equipment if operation is continued; or indicates improper design or other cause of failure of an item or part, which seriously impairs the equipment's operational capability.



[1]Based Upon Cooper-Harper Handling Qualities Rating Scale (Ref NASA TND-5153) And Definitions In Accordance With AR 310-25

*Definition of REQUIRED OPERATION involves designation of flight phase and/or subphases with accompanying conditions.

Figure 1. Handling Qualities Rating Scale

Shortcoming: An imperfection or malfunction occurring during the life cycle of equipment, which must be reported and which should be corrected to increase efficiency and to render the equipment completely serviceable. It will not cause an immediate breakdown, jeopardize safe operation, or materially reduce the usability of the materiel or end product.

APPENDIX E. TEST DATA

INDEX

FIGURE 1
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22716

REFERRED ROTOR SPEED = 258.1

NOTES:
1. NORMAL UTILITY CONFIGURATION
2. BALL CENTER TRIM CONDITION
3. AVERAGE LONGITUDINAL CENTER OF GRAVITY LOCATION AT FS 347.1
4. AVERAGE LATERAL CENTER OF GRAVITY LOCATION AT BL 0.1 LEFT
5. POINTS DERIVED FROM FIGURES 4 THRU 8

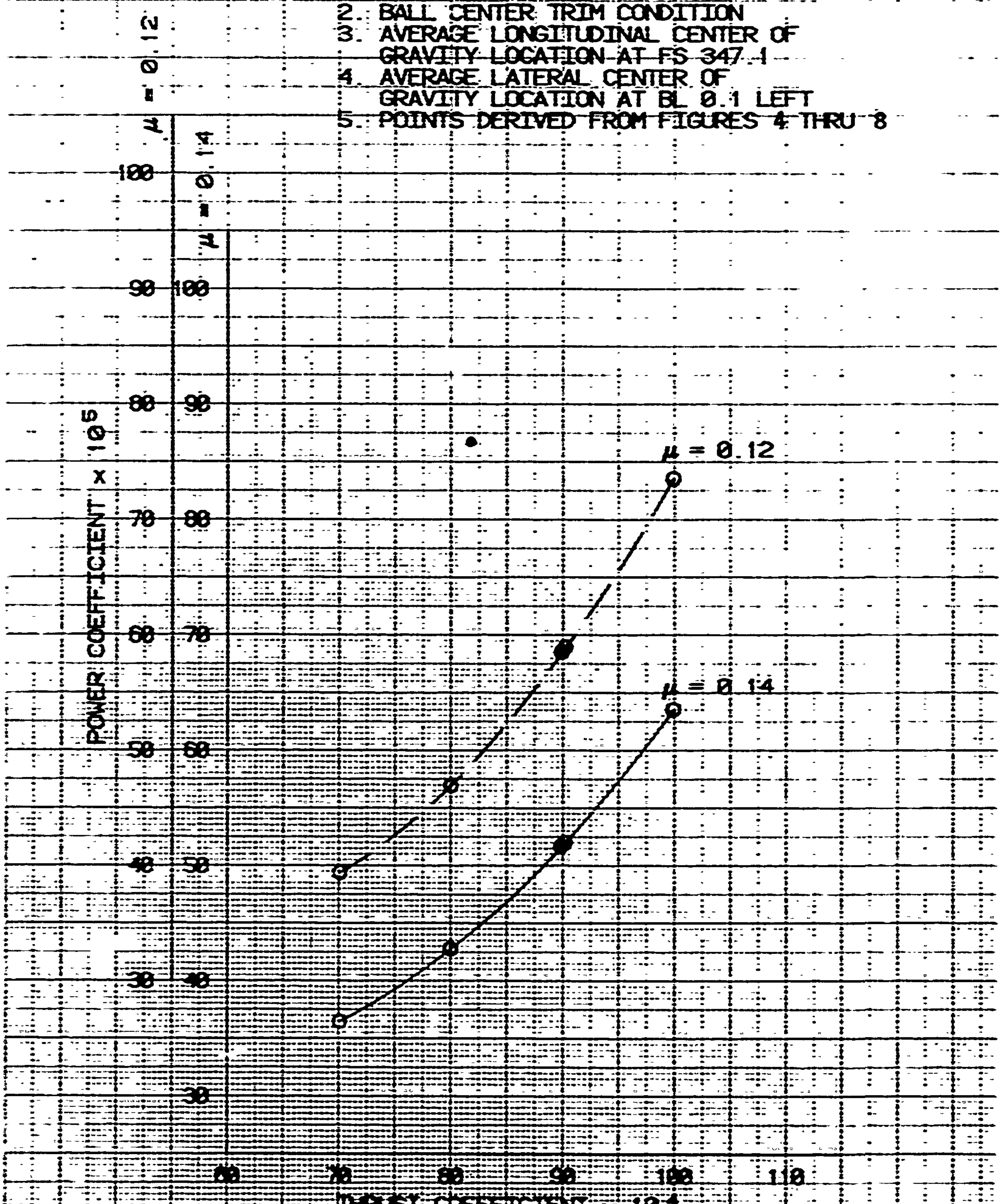


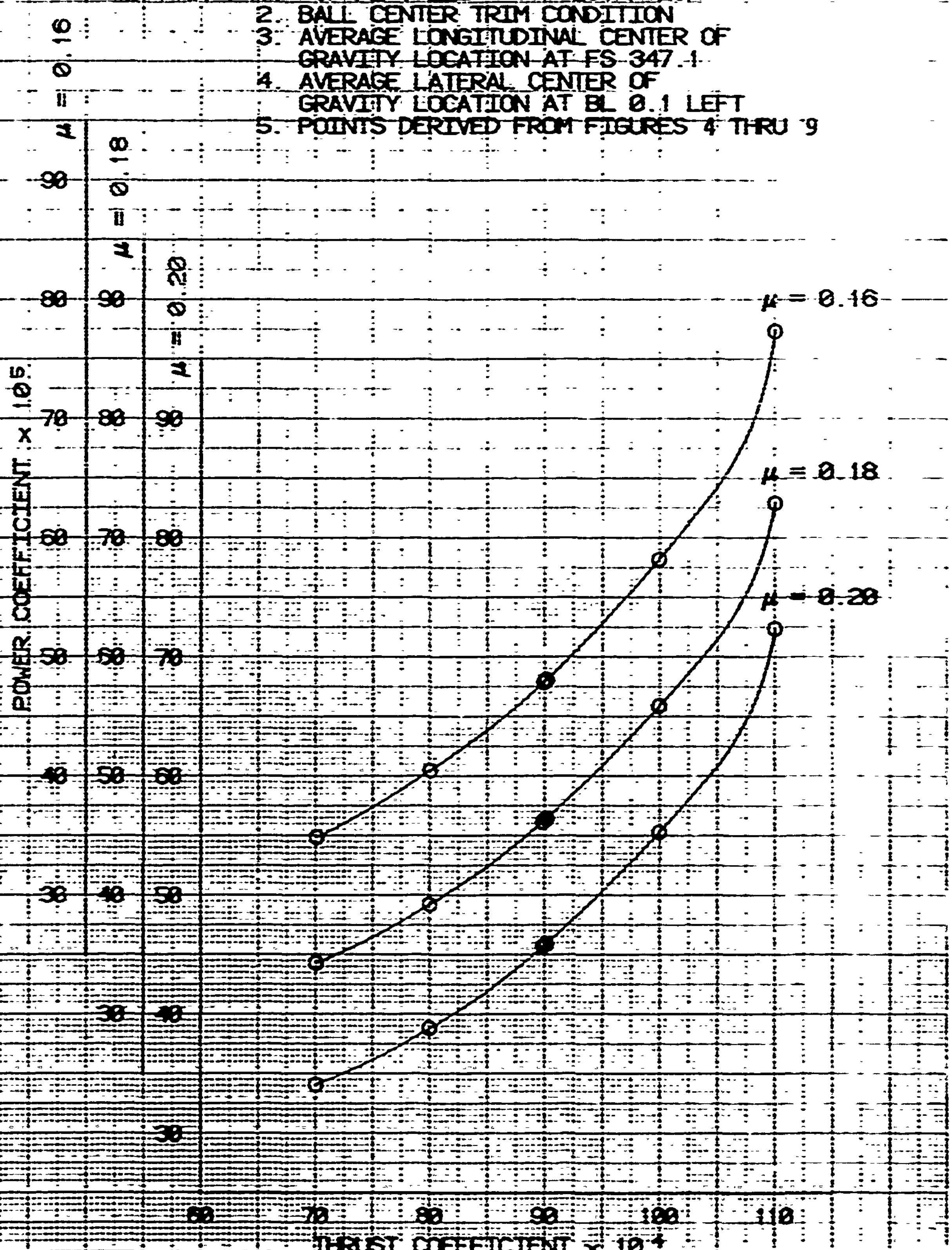
FIGURE 2

NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE

UH-60A USA S/N 77-22716

REFERRED ROTOR SPEED = 258.1

NOTES:
1. NORMAL UTILITY CONFIGURATION
2. BALL CENTER TRIM CONDITION
3. AVERAGE LONGITUDINAL CENTER OF GRAVITY LOCATION AT FS 347.1
4. AVERAGE LATERAL CENTER OF GRAVITY LOCATION AT BL 0.1 LEFT
5. POINTS DERIVED FROM FIGURES 4 THRU 9



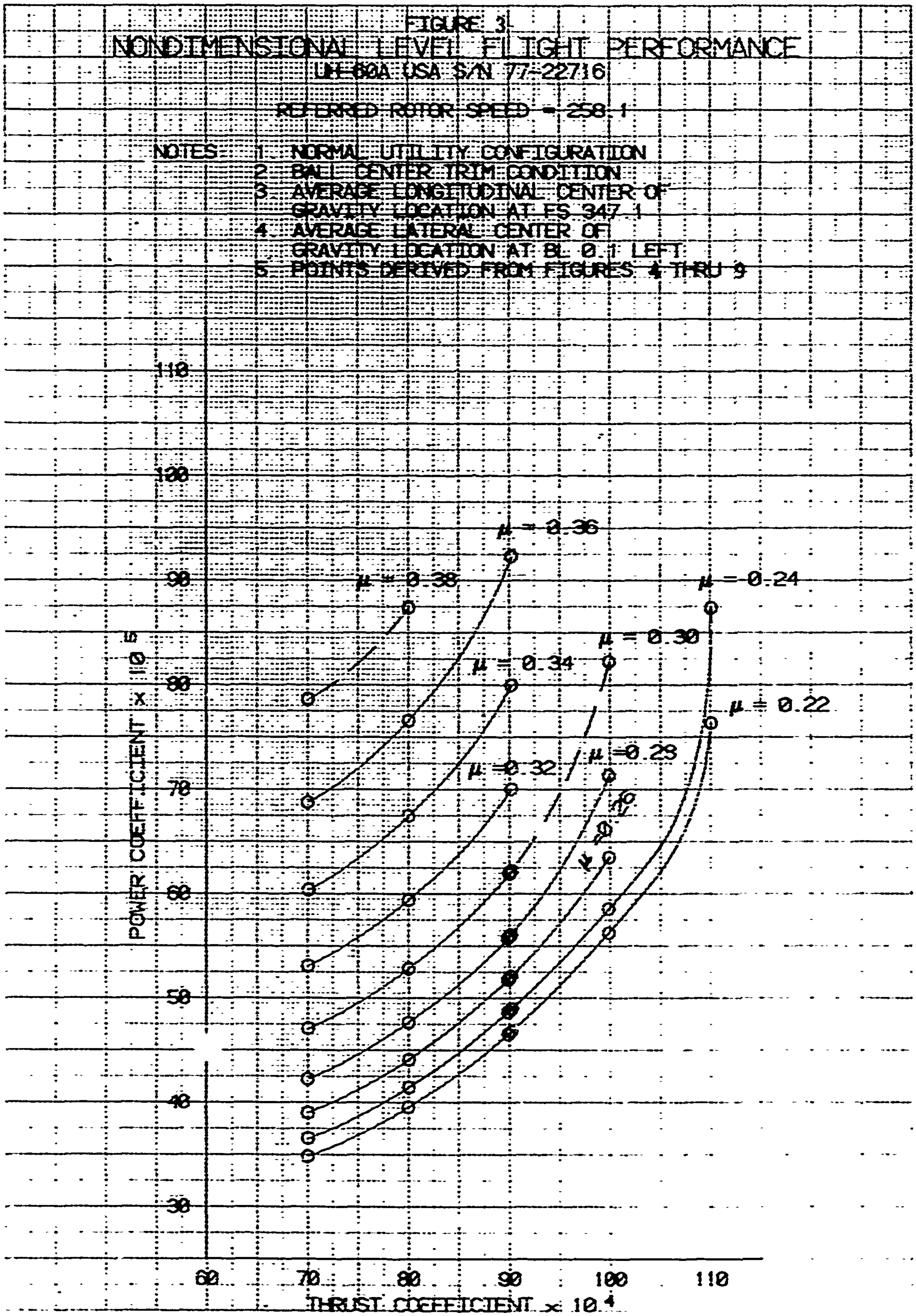
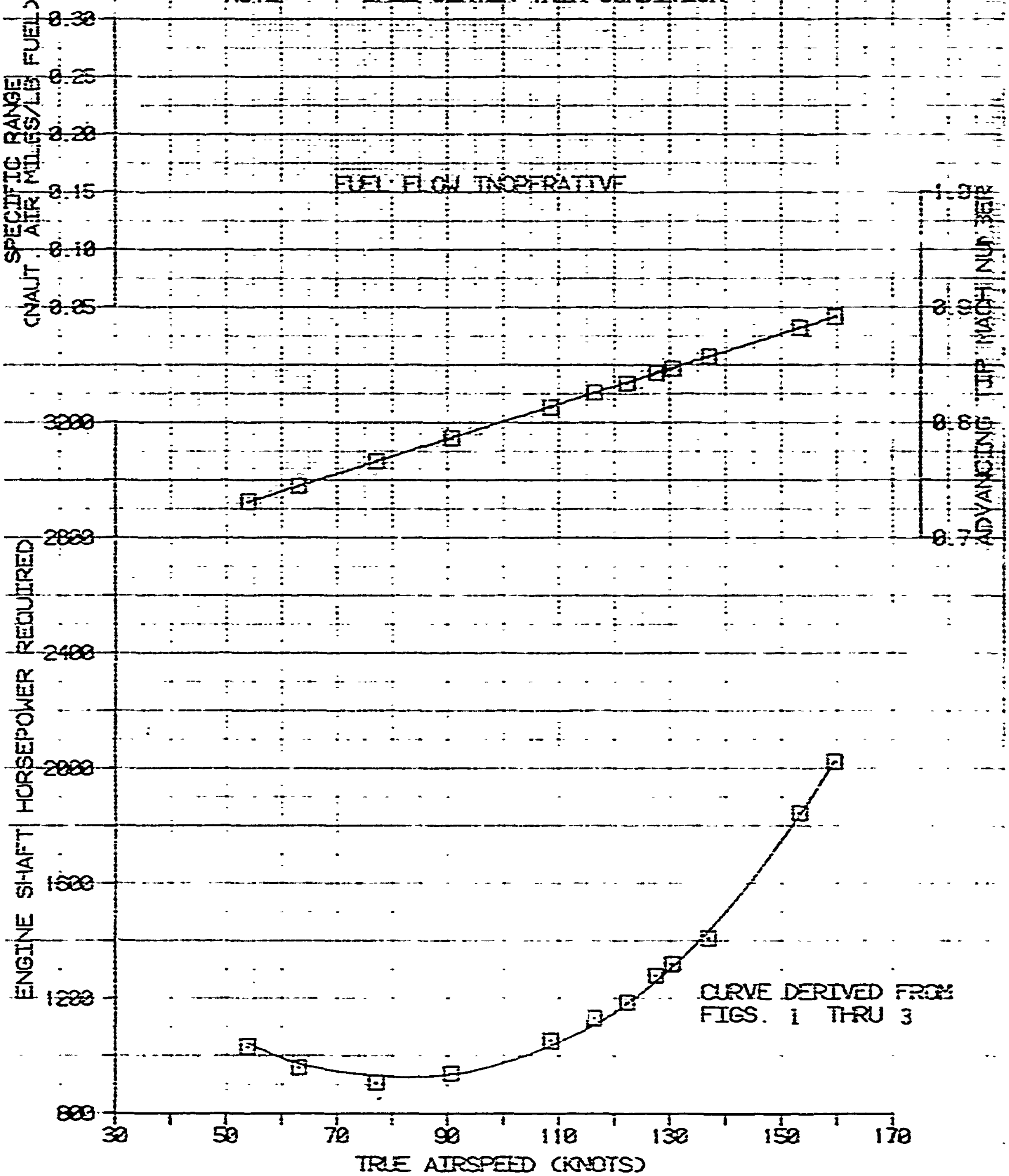


FIGURE 3
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22716
REFERRED ROTOR SPEED = 258.1
NOTES: 1. NORMAL UTILITY CONFIGURATION
2. BALL CENTER TRIM CONDITION
3. AVERAGE LONGITUDINAL CENTER OF GRAVITY LOCATION AT FS 347.1
4. AVERAGE LATERAL CENTER OF GRAVITY LOCATION AT BL 0.1 LEFT
5. POINTS DERIVED FROM FIGURES 4 THRU 9
μ = 0.36
μ = 0.38
μ = 0.24
μ = 0.30
μ = 0.34
μ = 0.22
μ = 0.28
μ = 0.32
POWER COEFFICIENT x 10^5
THRUST COEFFICIENT x 10^4
110
100
90
80
70
60
50
40
30
60
70
80
90
100
110

FIGURE 4
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG O.A.T. (DEG C)	AVG REF. ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
14470	347.0	0.4LT	10290	14.5	258.0	0.007010	NORM UTIL

NOTE: BALL CENTER TRIM CONDITION



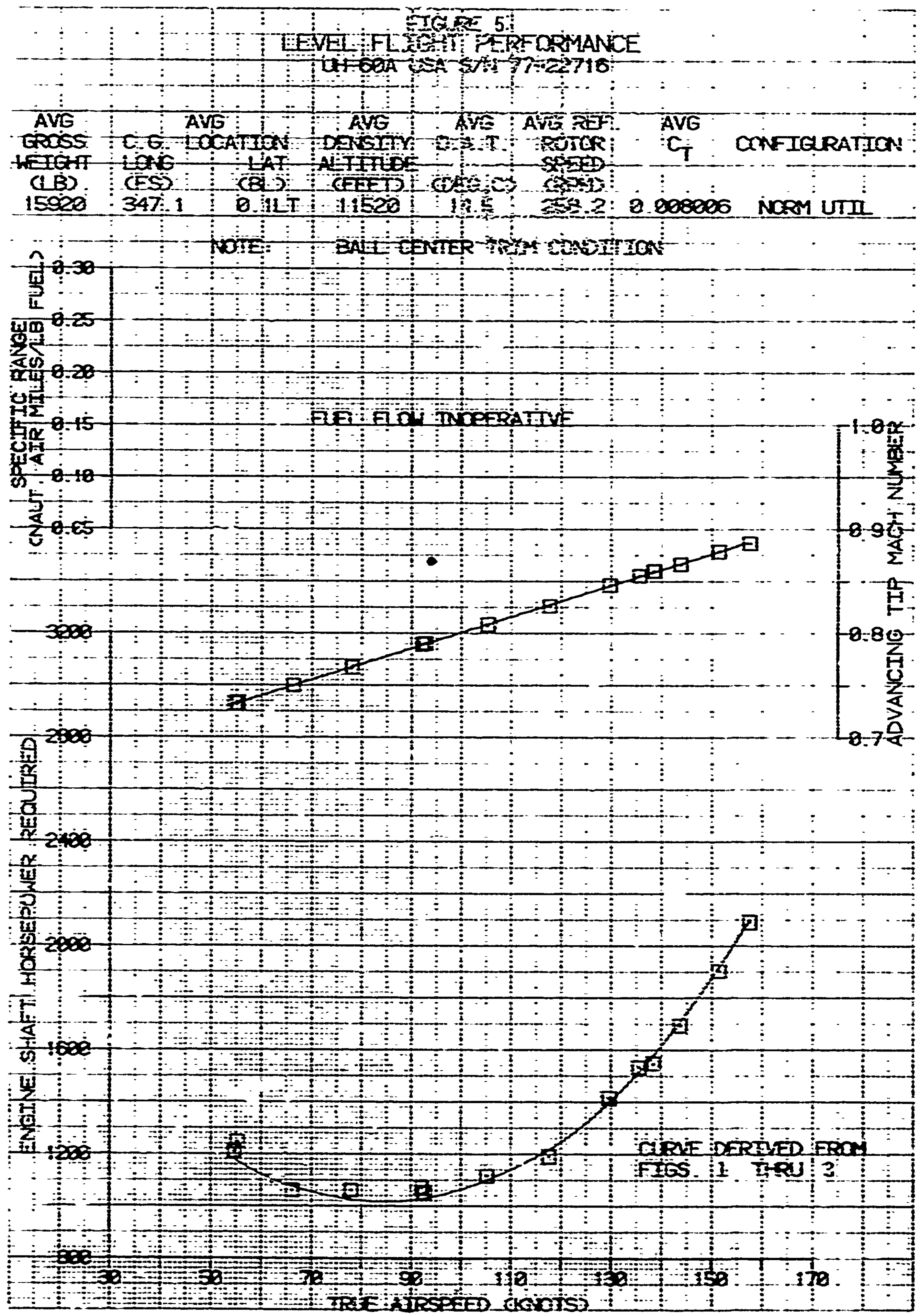


FIGURE 5
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22716
AVG GROSS WEIGHT (LB) 15920
AVG C.G. LOCATION LONG (FS) 347.1 LAT (BL) 0.1LT
AVG DENSITY ALTITUDE (FEET) 11520
AVG O.A.T. (DEG C) 11.5
AVG REF. ROTOR SPEED (RPM) 258.2
AVG C_T 0.008006
CONFIGURATION NORM UTIL
NOTE: BALL CENTER TRIM CONDITION
SPECIFIC RANGE (NAUT. AIR MILES/LB FUEL)
0.30
0.25
0.20
0.15
0.10
0.05
FUEL FLOW INOPERATIVE
ADVANCING TIP MACH NUMBER
1.0
0.9
0.8
0.7
ENGINE SHAFT HORSEPOWER REQUIRED
3200
2800
2400
2000
1600
1200
800
CURVE DERIVED FROM FIGS. 1 THRU 3
30
50
70
90
110
130
150
170
TRUE AIRSPEED (KNOTS)

FIGURE 6
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	C.G. LOCATION LONG (FS)	C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG O.A.T. (DEG C)	AVG REF. ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
21370	347.1(FWD)	0.1LT	6610	22.0	258.1	0.008992	NORM UTIL

NOTE: BALL CENTER TRIM CONDITION

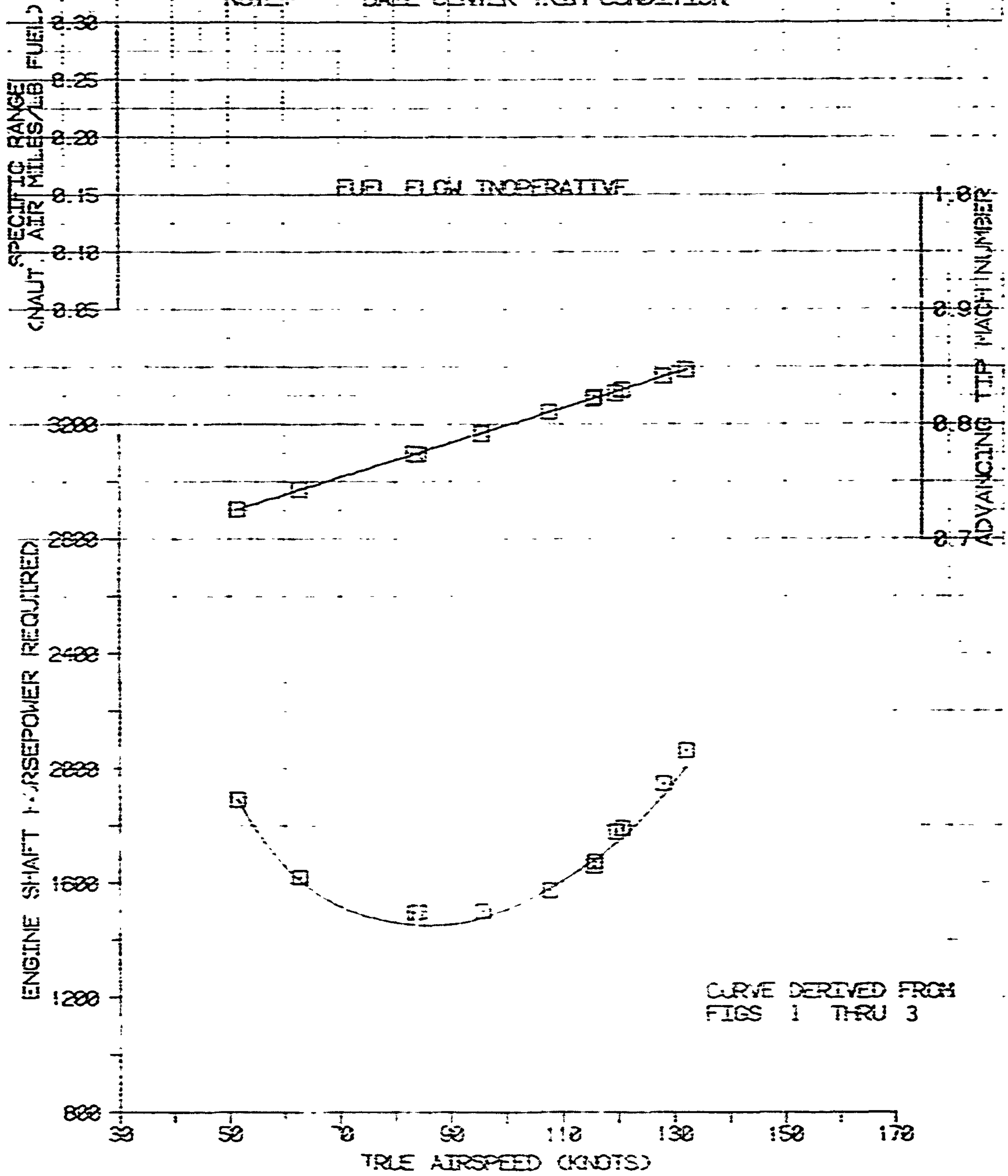
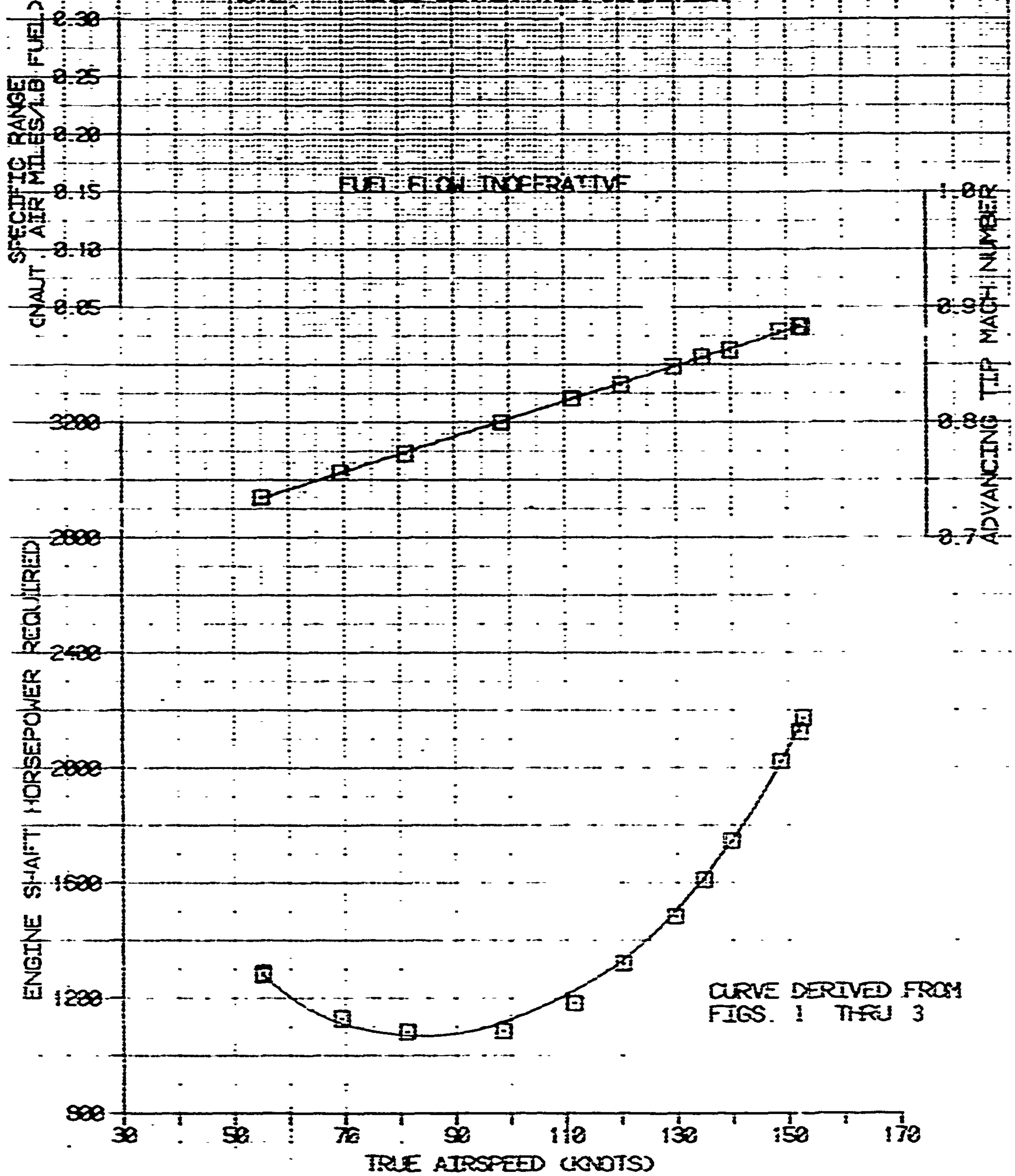


FIGURE 7
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG O.A.T. (DEG C)	AVG REF ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
16190	347.1	0.1LT	13840	7.0	258.0	0.009019	NORM UTIL

NOTE: BALL CENTER TRIM CONDITION



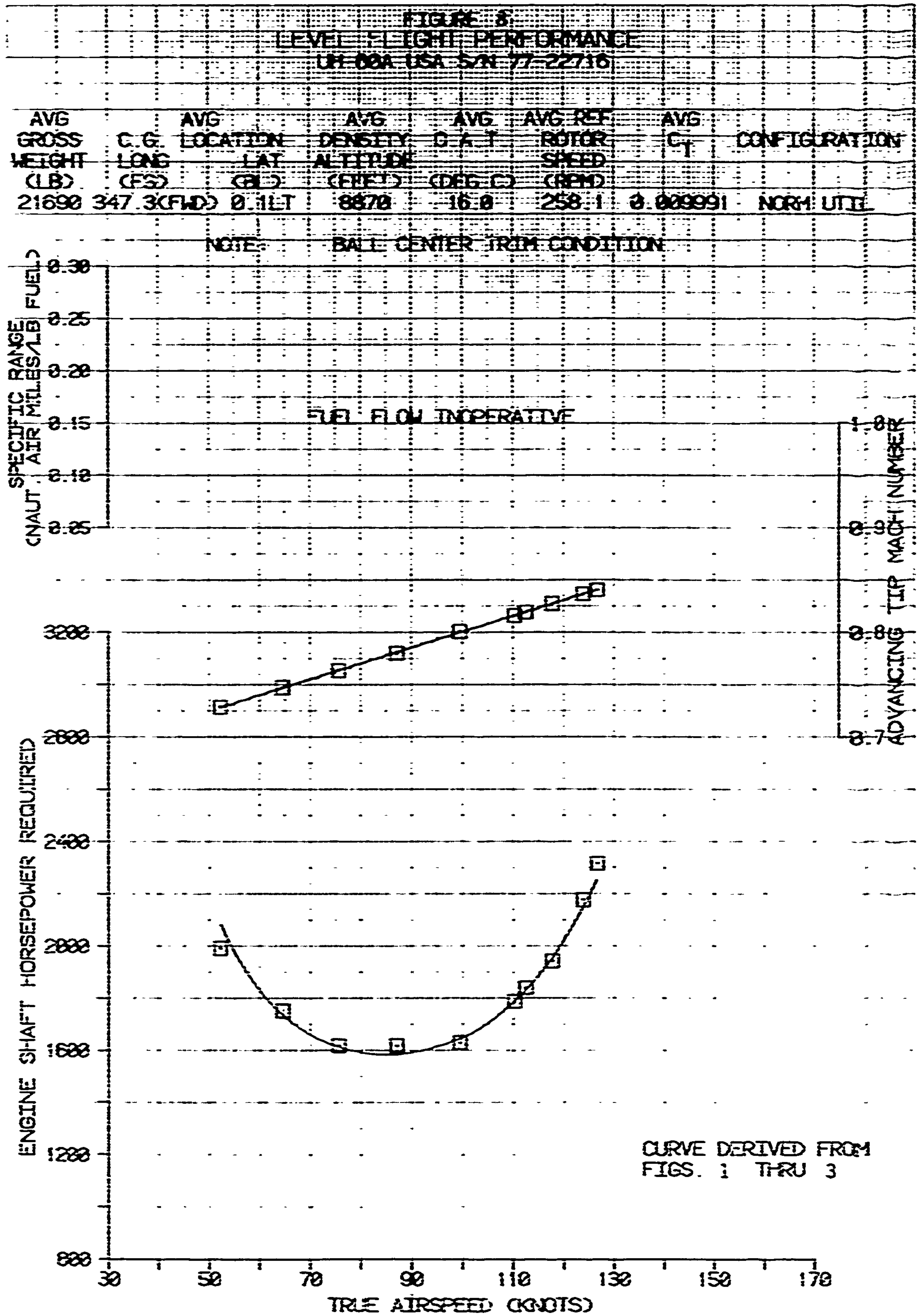


FIGURE 8
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22716
AVG GROSS WEIGHT (LB)
21690
AVG C.G. LOCATION LONG (FS)
347.3(FWD)
LAT (BL)
0.1LT
AVG DENSITY ALTITUDE (FEET)
8870
AVG O.A.T (DEG C)
16.0
AVG REF ROTOR SPEED (RPM)
258.1
AVG C_T
0.009991
CONFIGURATION
NORM UTIL
NOTE: BALL CENTER TRIM CONDITION
SPECIFIC RANGE (NAUT. AIR MILES/LB FUEL)
FUEL FLOW INOPERATIVE
ADVANCING TIP MACH NUMBER
ENGINE SHAFT HORSEPOWER REQUIRED
CURVE DERIVED FROM FIGS. 1 THRU 3
TRUE AIRSPEED (KNOTS)

FIGURE 9
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG O.A.T. (DEG C)	AVG REF. ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
21480	347.2(FWD)	0.1LT	11400	8.5	258.0	0.011007	NORM UTIL

NOTE: BALL CENTER TRIM CONDITION

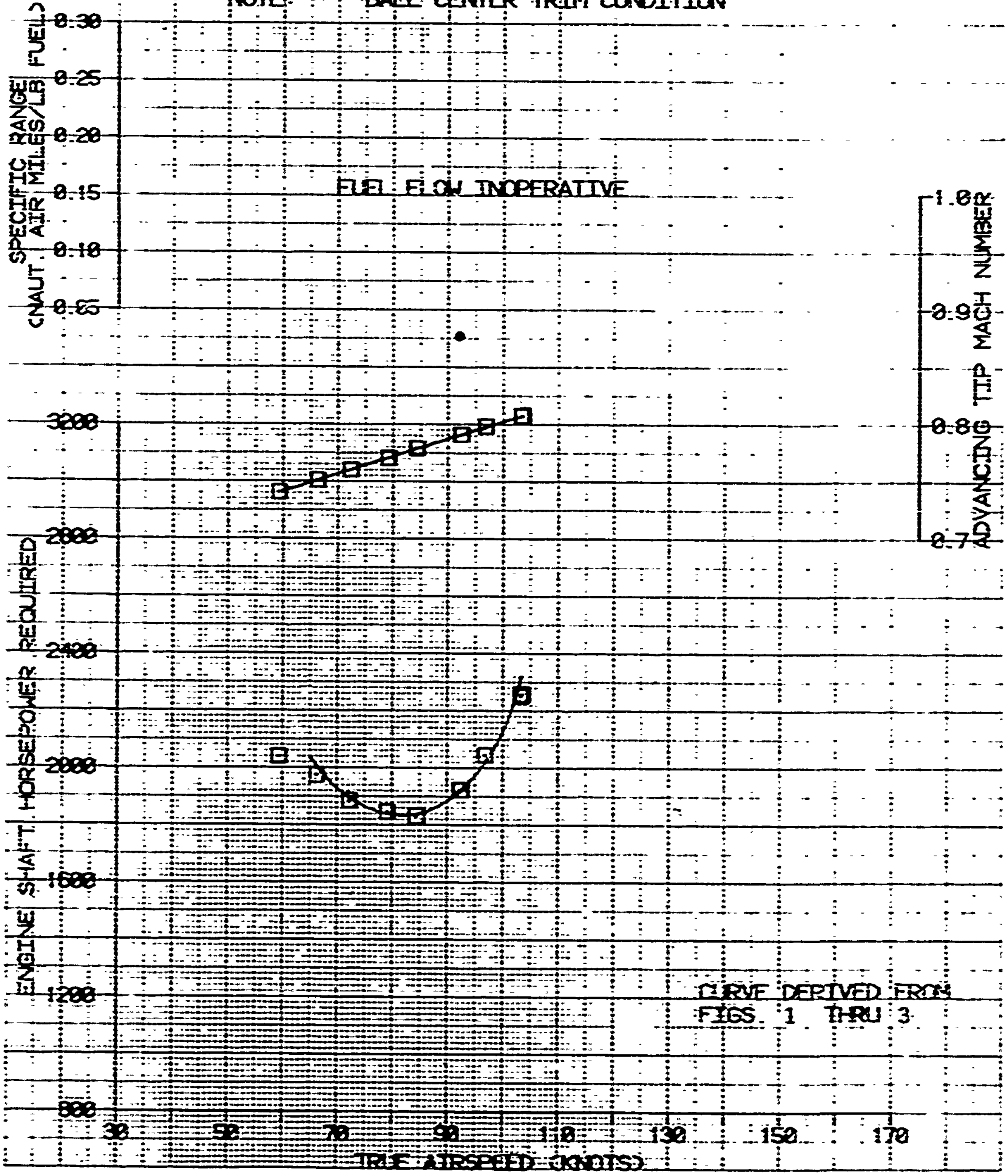
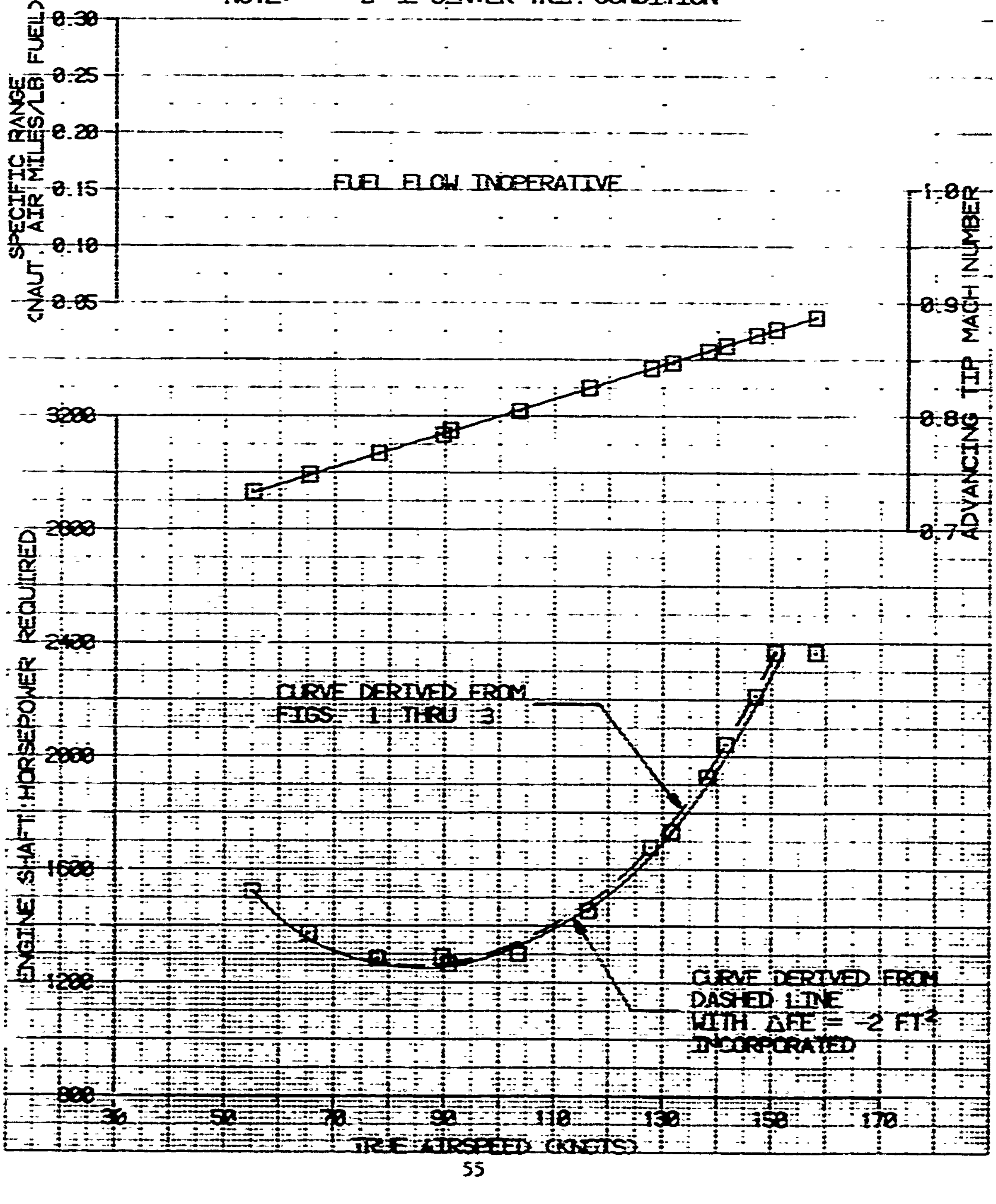


FIGURE 10
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG O.A.T. (DEG.C)	AVG REF. ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
18790	360.2(AFT)	0.1LT	10110	16.0	258.0	0.009004	NORM UTIL

NOTE: BALL CENTER TRIM CONDITION



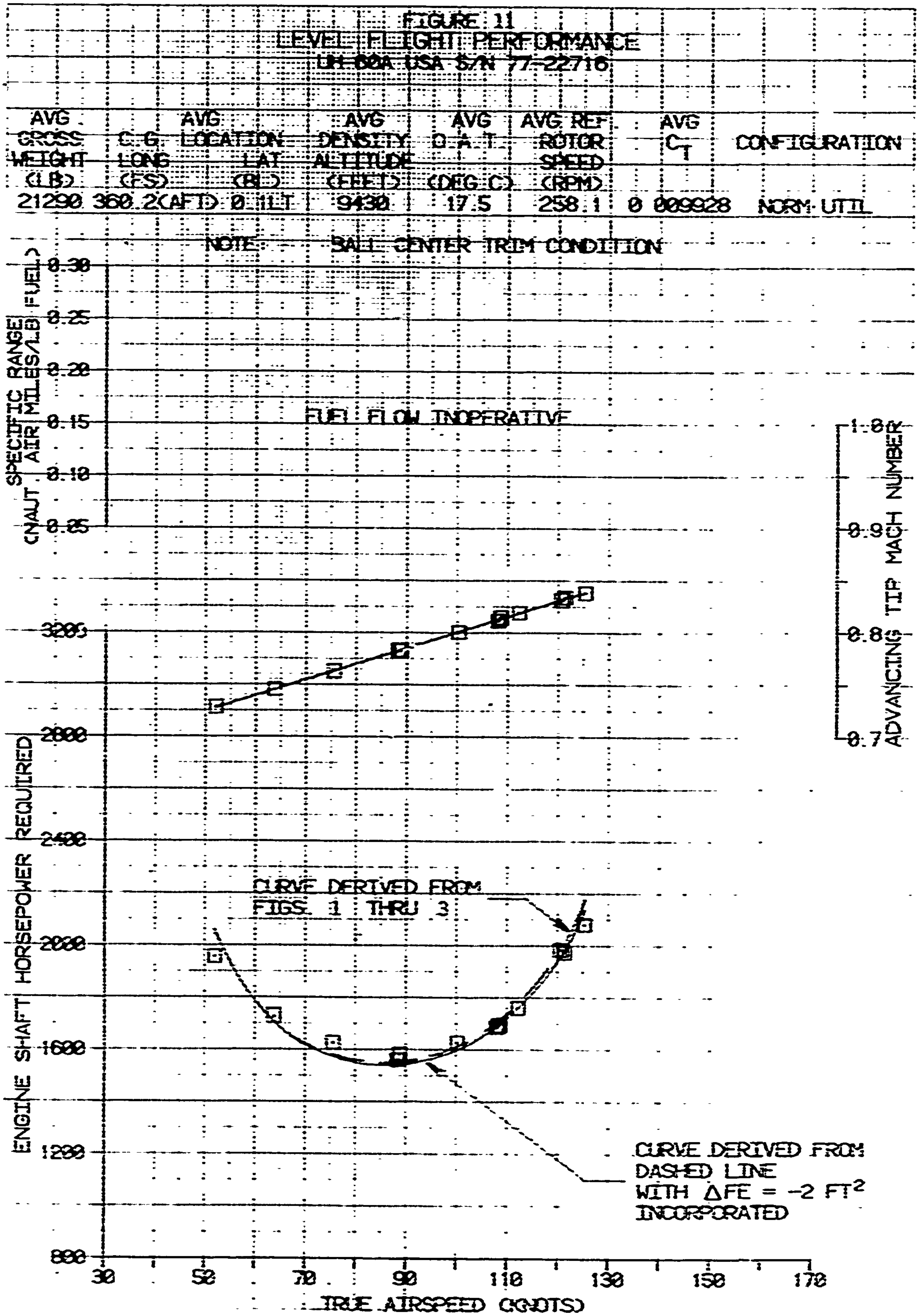


FIGURE 11
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22716
AVG GROSS WEIGHT (LB)
AVG C.G. LOCATION
LONG (FS)
LAT (BL)
AVG DENSITY ALTITUDE (FEET)
AVG O.A.T. (DEG C)
AVG REF ROTOR SPEED (RPM)
AVG C_T
CONFIGURATION
21290
360.2(AFT)
0.1LT
9430
17.5
258.1
0.009928
NORM UTIL
NOTE: BALL CENTER TRIM CONDITION
SPECIFIC RANGE (NAUT AIR MILES/LB FUEL)
0.30
0.25
0.20
0.15
0.10
0.05
FUEL FLOW INOPERATIVE
ADVANCING TIP MACH NUMBER
1.00
0.9
0.8
0.7
ENGINE SHAFT HORSEPOWER REQUIRED
3200
2800
2400
2000
1600
1200
800
CURVE DERIVED FROM
FIGS. 1 THRU 3
CURVE DERIVED FROM
DASHED LINE
WITH ΔFE = -2 FT²
INCORPORATED
30
50
70
90
110
130
150
170
TRUE AIRSPEED (KNOTS)

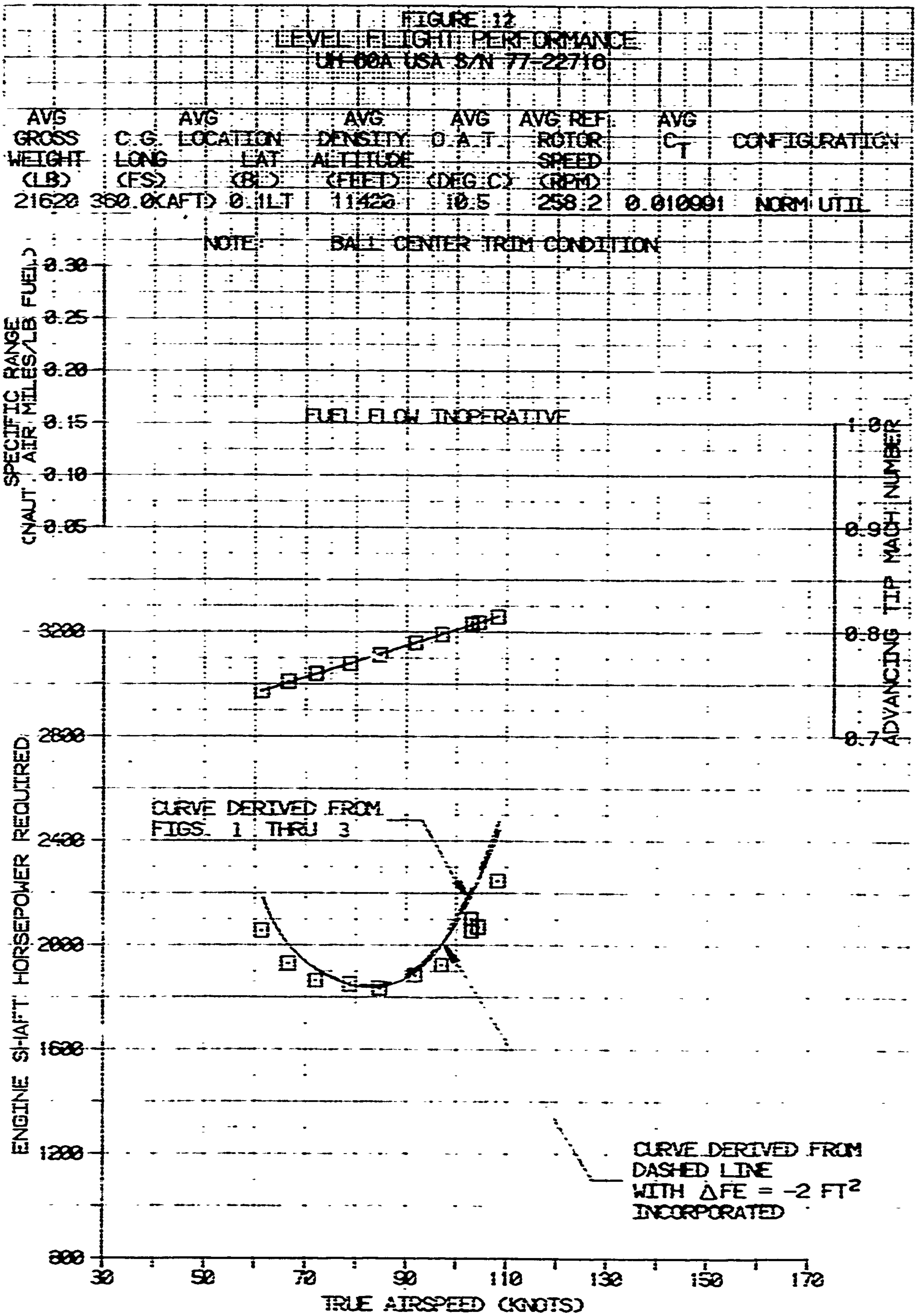


FIGURE 12
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22716
AVG GROSS WEIGHT (LB) 21620
AVG C.G. LOCATION LONG (FS) 360.0(AFT) LAT (BL) 0.1LT
AVG DENSITY ALTITUDE (FEET) 11420
AVG O.A.T. (DEG C) 10.5
AVG REF. ROTOR SPEED (RPM) 258.2
AVG C_T 0.010991
CONFIGURATION NORM UTIL
NOTE: BALL CENTER TRIM CONDITION
SPECIFIC RANGE (NAUT. AIR MILES/LB FUEL)
FUEL FLOW INOPERATIVE
ADVANCING TIP MACH NUMBER
ENGINE SHAFT HORSEPOWER REQUIRED
CURVE DERIVED FROM FIGS. 1 THRU 3
CURVE DERIVED FROM DASHED LINE WITH ΔFE = -2 FT²
INCORPORATED
TRUE AIRSPEED (KNOTS)

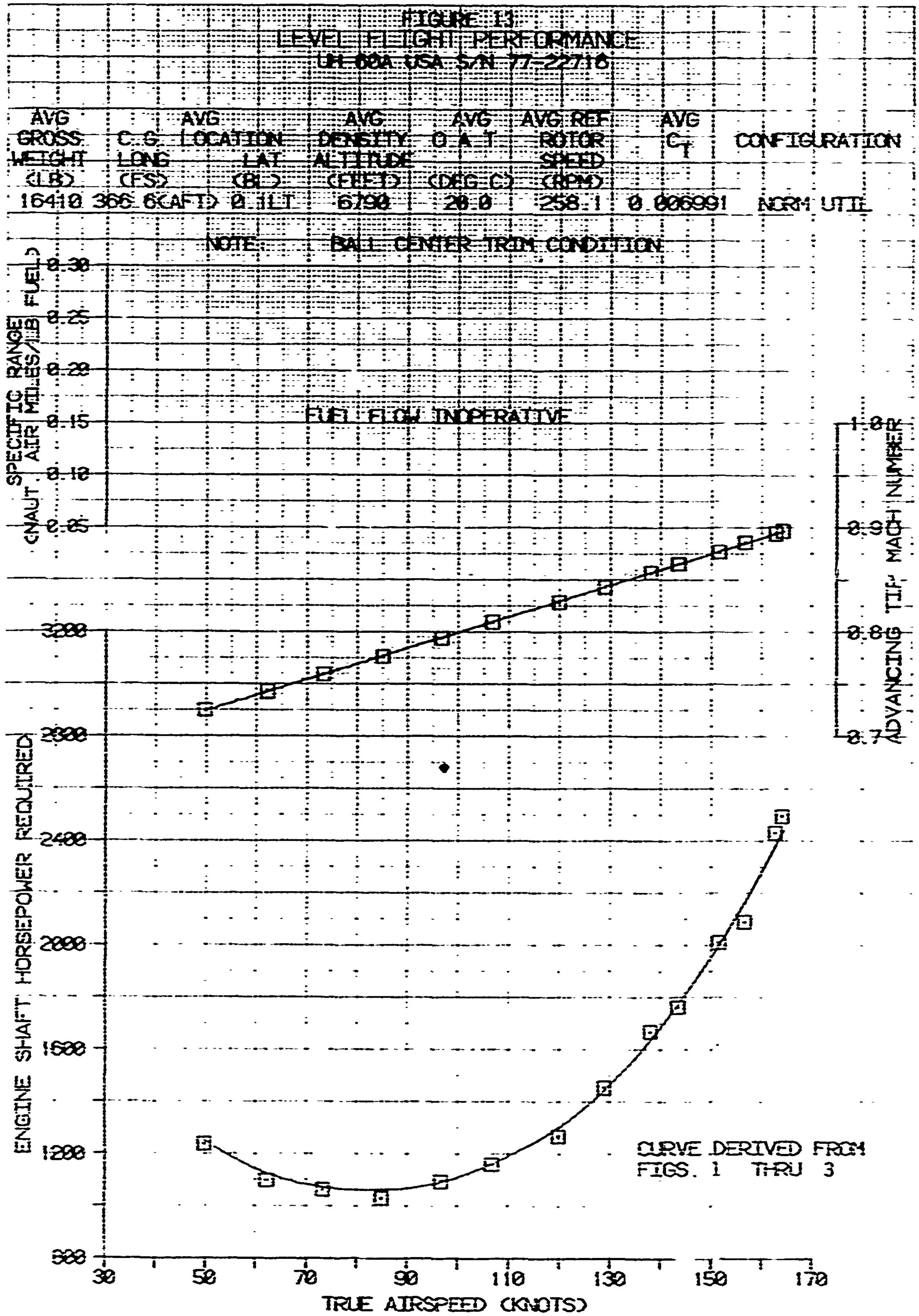


FIGURE 13
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22716
AVG GROSS WEIGHT (LB)
AVG C.G. LOCATION LONG (FS) LAT (BL)
AVG DENSITY ALTITUDE (FEET)
AVG O.A.T. (DEG C)
AVG REF ROTOR SPEED (RPM)
AVG C_T
CONFIGURATION
16410 366.6(AFT) 0.1LT 6790 20.0 258.1 0.006991 NORM UTIL
NOTE: BALL CENTER TRIM CONDITION
SPECIFIC RANGE (NAUT. AIR MILES/LB FUEL)
0.30
0.25
0.20
0.15
0.10
0.05
FUEL FLOW INOPERATIVE
ADVANCING TIP MACH NUMBER
1.00
0.90
0.80
0.7
ENGINE SHAFT HORSEPOWER REQUIRED
3200
2800
2400
2000
1600
1200
800
CURVE DERIVED FROM FIGS. 1 THRU 3
30
50
70
90
110
130
150
170
TRUE AIRSPEED (KNOTS)

FIGURE 14
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG O.A.T. (DEG C)	AVG REF ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
16560	366.6(AFT)	0.1LT	10070	13.0	258.1	0.008003	NORM UTIL

NOTE: BALL CENTER TRIM CONDITION

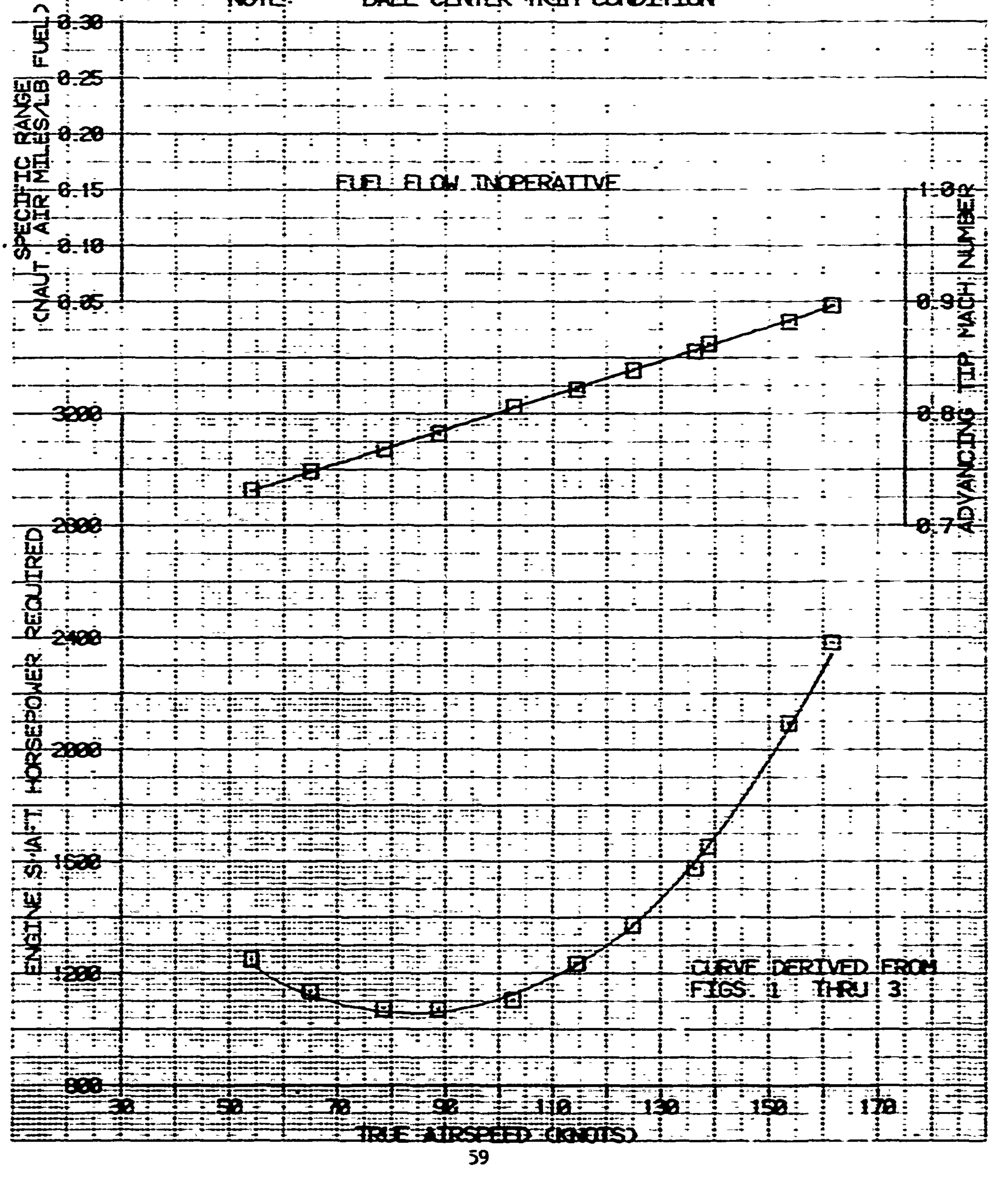


FIGURE 15
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG O.A.T. (DEG C)	AVG REF ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
16550	366.9(AFT)	0.1LT	13210	8.5	258.0	0.008986	NORM UTIL

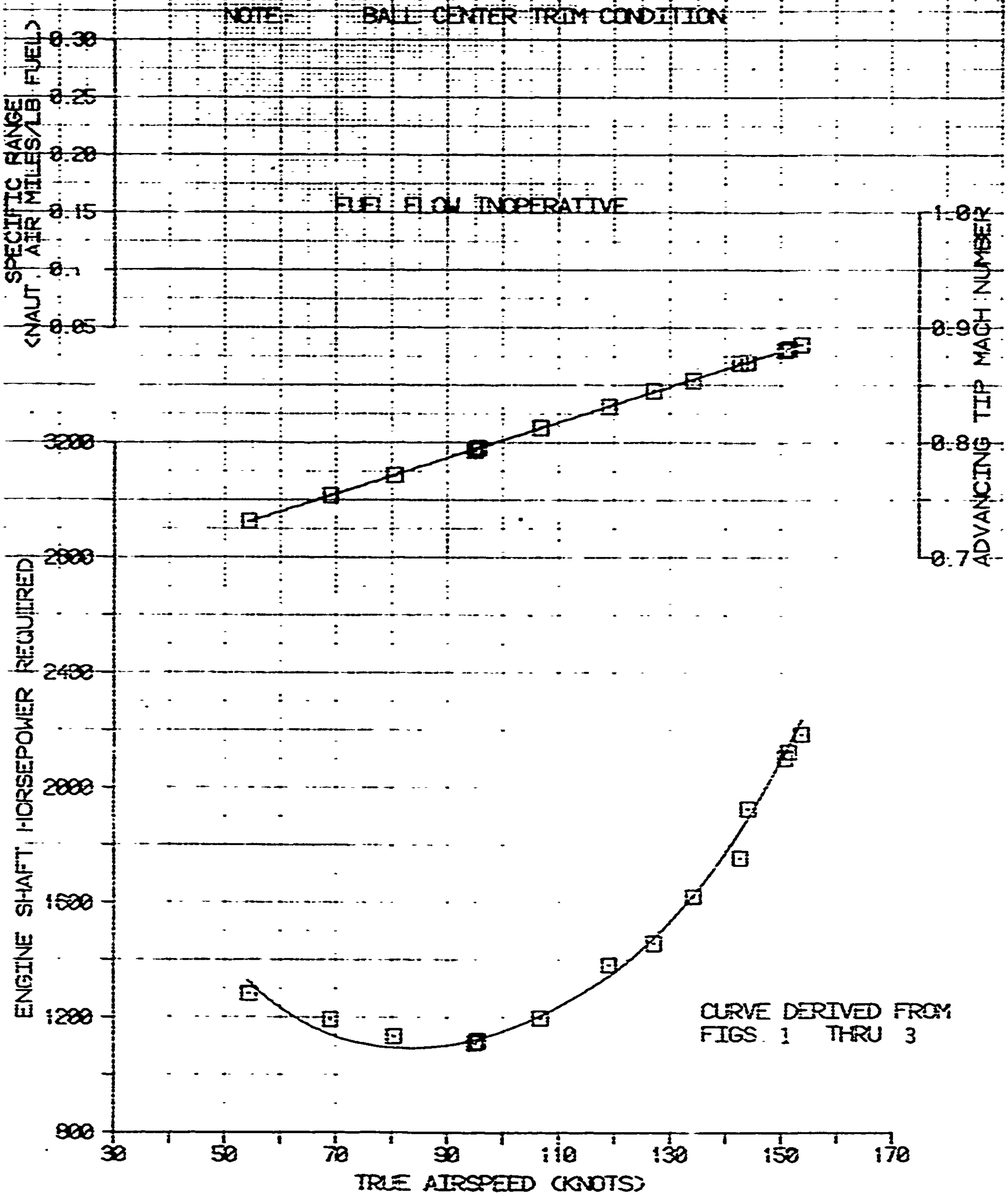


FIGURE 16

INHERENT SIDESLIP

UH-60A USA S/N 77-22716 and S/N 82-23748

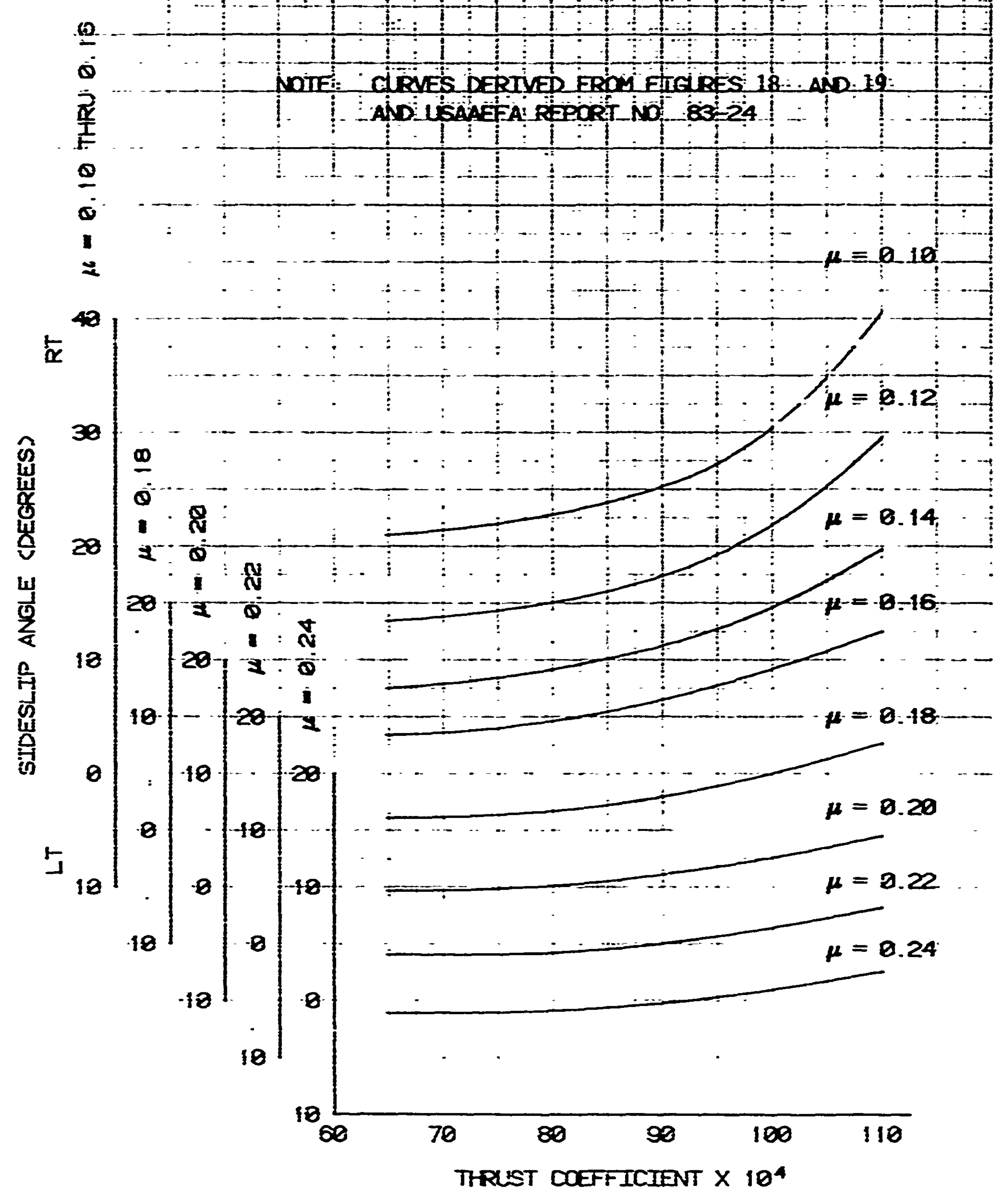


FIGURE 17
INHERENT SIDESLIP
UH-60A USA S/N 77-22716 and S/N 82-23748

NOTE: CURVES DERIVED FROM FIGURES 18 AND 19
AND USAAEFA REPORT NO. 83-24

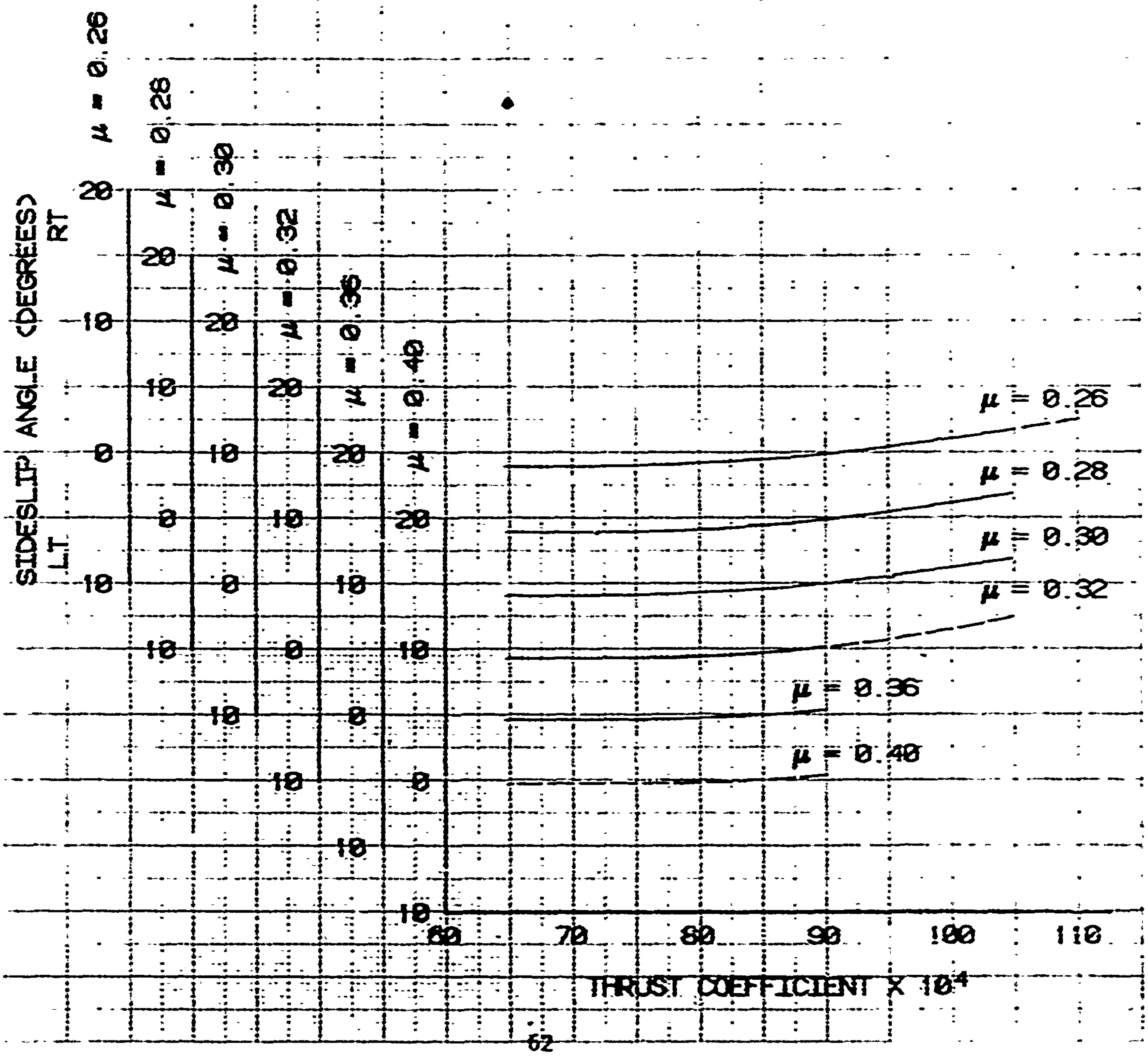


FIGURE 18

SIDESLIP IN BALL CENTER LEVEL FLIGHT

UH-60A USA S/N 77-22716

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
⊡	21480	347.2(FWD)	0.1LT	11400	8.5	258.0	0.011007
⊙	21690	347.3(FWD)	0.1LT	8870	18.0	258.1	0.009991
△	16190	347.1	0.1LT	13840	7.0	258.0	0.009019
◇	21370	347.1(FWD)	0.1LT	6810	22.0	258.1	0.008992
★	15920	347.1	0.1LT	11520	14.5	258.2	0.008006
+	14470	347.0	0.1LT	10200	14.5	258.0	0.007010

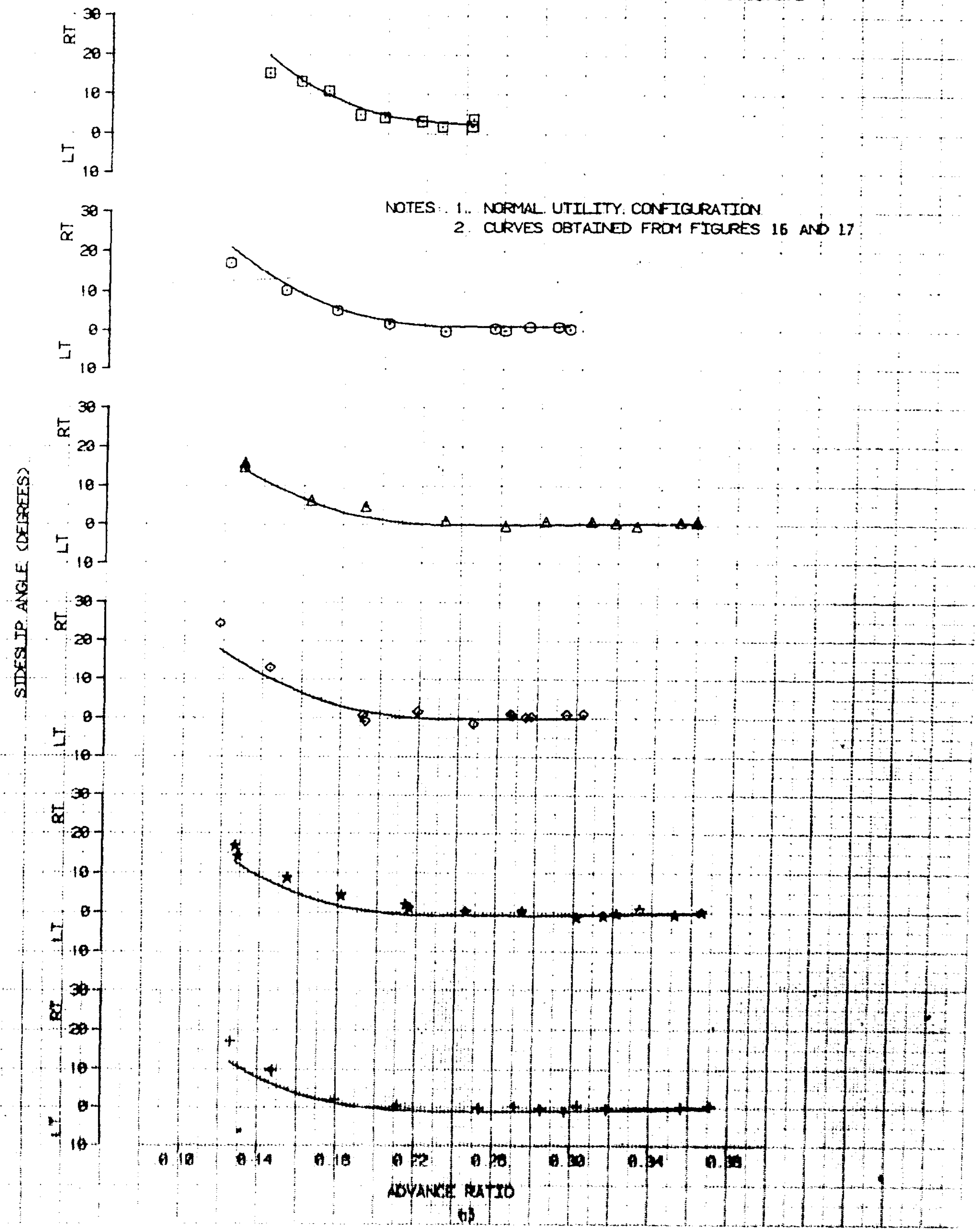


FIGURE 19
SIDESLIP IN BALL CENTER LEVEL FLIGHT
UH-60A USA S/N 77-22716

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
□	21620	360.0(AFT)	0.1LT	11420	10.5	258.2	0.010991
⊙	21290	360.2(AFT)	0.1LT	9430	17.5	258.1	0.009628
△	18790	360.2(AFT)	0.1LT	10110	16.0	258.0	0.009004
◇	16550	366.9(AFT)	0.1LT	13210	8.5	258.0	0.008986
★	16560	366.6(AFT)	0.1LT	10070	13.0	258.1	0.008003
+	16410	366.6(AFT)	0.1LT	6790	20.0	258.1	0.006991

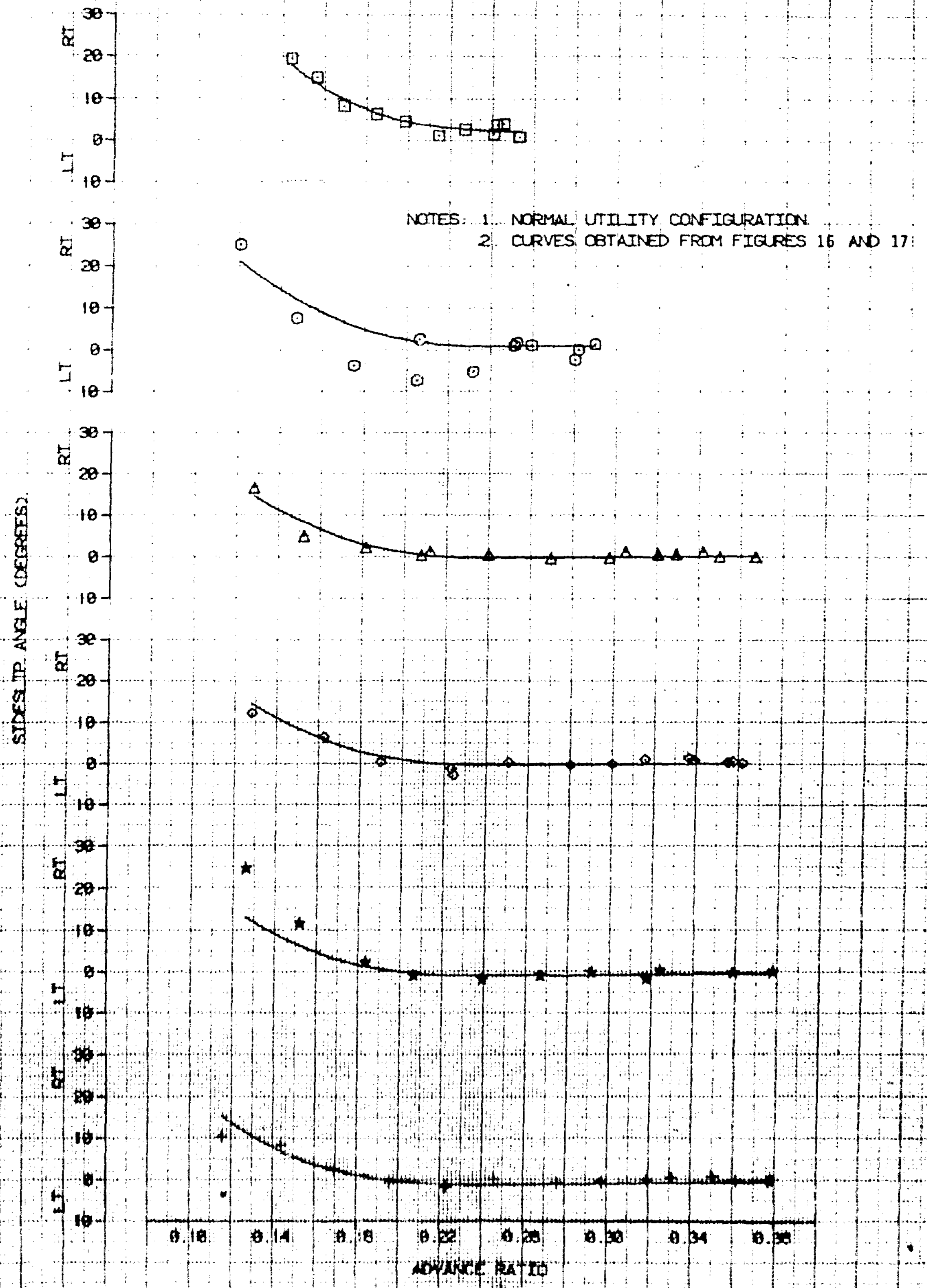


FIGURE 20

CHANGE IN EQUIVALENT FLAT PLATE AREA vs. SIDESLIP

UH-60A USA S/N 77-22716 and S/N 82-23748

SYMBOL	AVG TRUE AIRSPEED (KT)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG REFERRED ROTOR SPEED (RPM)	AVG CT	CONFIGURATION
□	102	347.5	0.4LT	258	0.006499	NORM UTIL (ESSS FAIRINGS)
⊙	120	347.3	0.3LT	257	0.006554	NORM UTIL (ESSS FAIRINGS)
△	145	347.3	0.3LT	258	0.006529	NORM UTIL (ESSS FAIRINGS)
+	157	346.9	0.3LT	257	0.006542	NORM UTIL (ESSS FAIRINGS)
◇	92	347.1	0.2LT	258	0.009013	NORM UTIL
⊠	100	347.3	0.3LT	258	0.009014	NORM UTIL (ESSS FAIRINGS)
⌑	104	347.6	0.1LT	265	0.009132	NORM UTIL (ESSS FAIRINGS)
⊗	117	347.3	0.0	258	0.009082	NORM UTIL
⊞	124	347.3	0.3LT	258	0.008996	NORM UTIL (ESSS FAIRINGS)
▽	140	347.0	0.3LT	257	0.009041	NORM UTIL (ESSS FAIRINGS)
▲	140	347.2	0.0	258	0.009070	NORM UTIL
*	78	347.1	0.3LT	257	0.010572	NORM UTIL (ESSS FAIRINGS)
×	85	347.4	0.2LT	275	0.010575	NORM UTIL (ESSS FAIRINGS)
↑	104	347.2	0.3LT	258	0.010561	NORM UTIL (ESSS FAIRINGS)
↓	75	347.0	0.0	259	0.011033	NORM UTIL
▪	90	347.0	0.0	258	0.011115	NORM UTIL

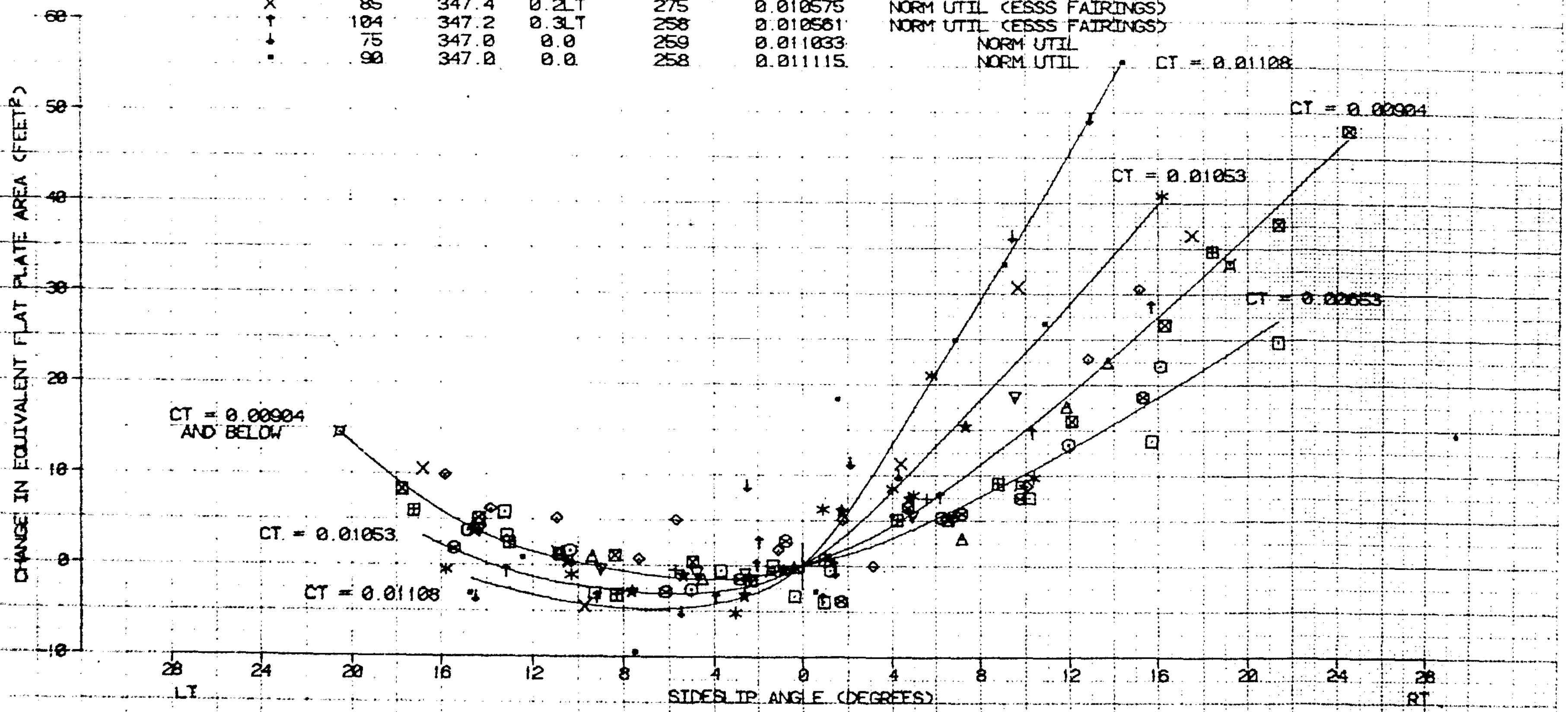


FIGURE 21

CONTROL POSITIONS IN TRIMMED FOWARD FLIGHT

UH-60A USA S/N 77-22716

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
⊡	15920	347.1(FWD)	0.0	11500	14.5	258	LEVEL	ON
⊙	16480	364.9(AFT)	0.0	10220	13.0	257	LEVEL	ON

NOTE: NORMAL UTILITY CONFIGURATION

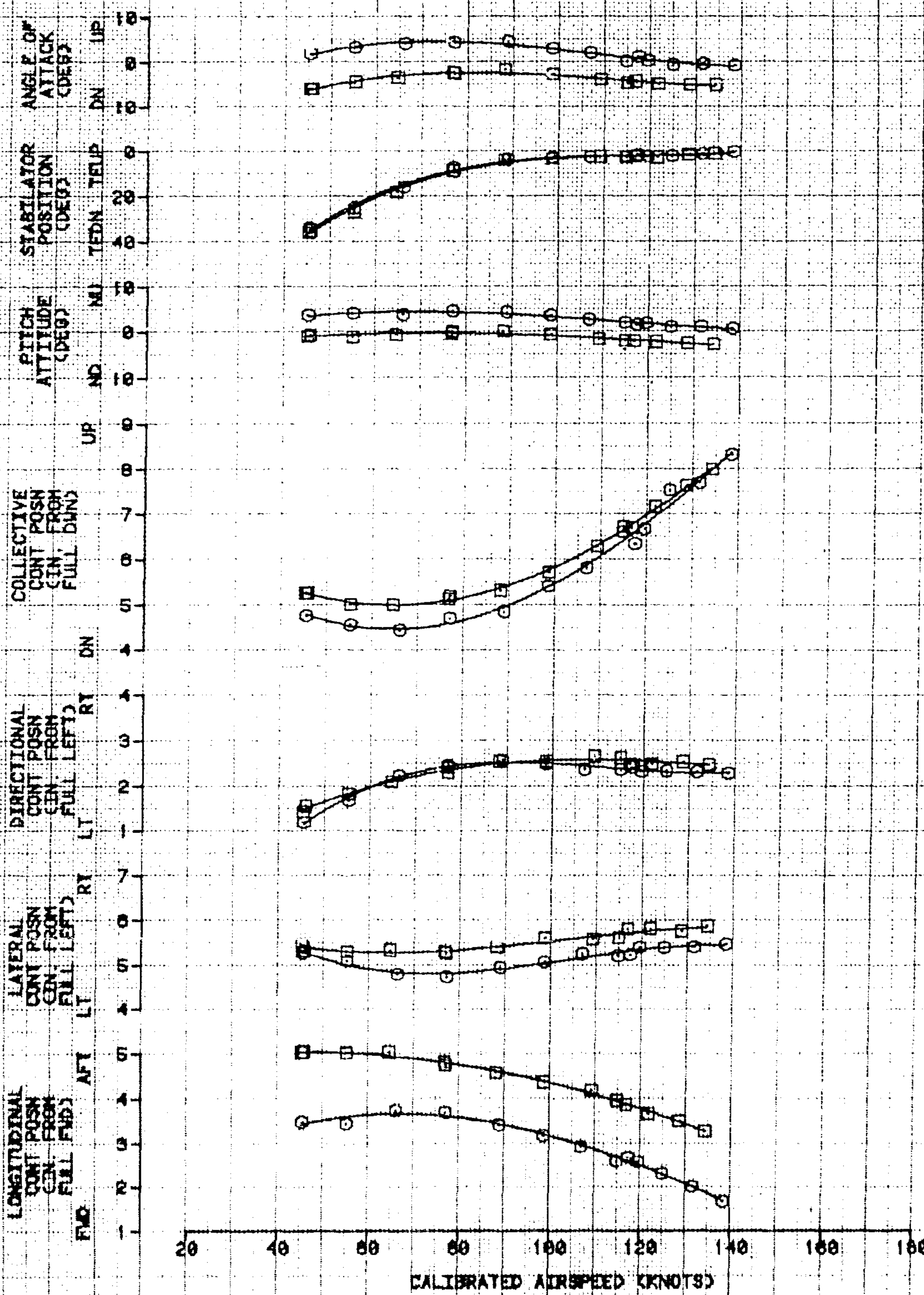


FIGURE 22
CONTROL POSITIONS IN TRIMMED FOWARD FLIGHT
UH-60A USA S/N 77-22716

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
⊡	21660	347.3(FWD)	0.0	8920	16.0	259	LEVEL	ON
⊙	21260	360.1(AFT)	0.0	9460	17.5	259	LEVEL	ON

NOTES: 1. PBA LOCKED IN CENTER POSITION
2. NORMAL UTILITY CONFIGURATION

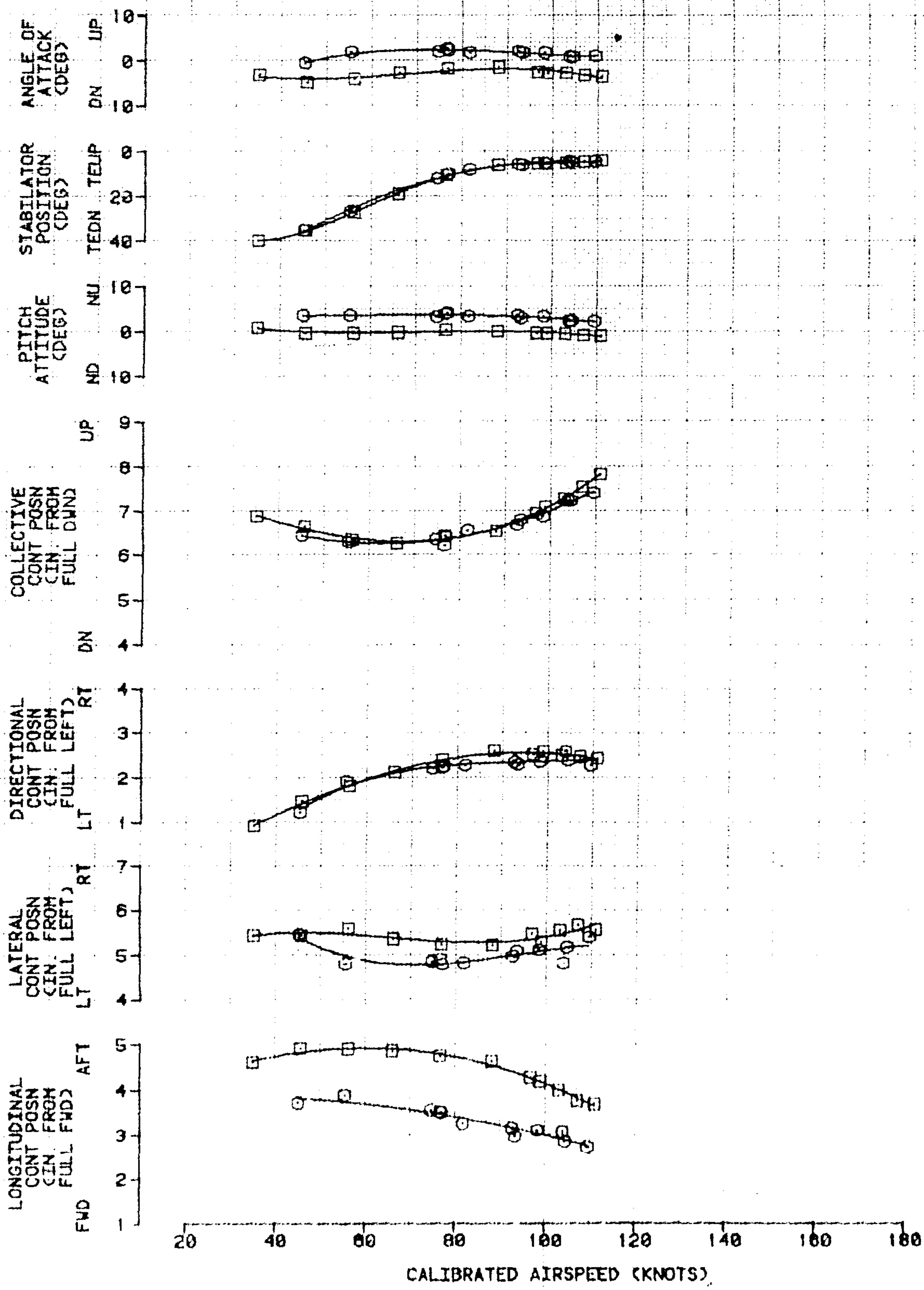


FIGURE 23

COLLECTIVE-FIXED STATIC LONGITUDINAL STABILITY

UH-60A USA S/N 77-22716

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
⊡	16020	364.8(AFT)	0.0	5720	24.5	258	LEVEL	ON
⊙	16260	365.2(AFT)	0.0	6000	23.0	258	LEVEL	ON

NOTES: 1. SHADED SYMBOLS DENOTE TRIM
2. NORMAL UTILITY CONFIGURATION

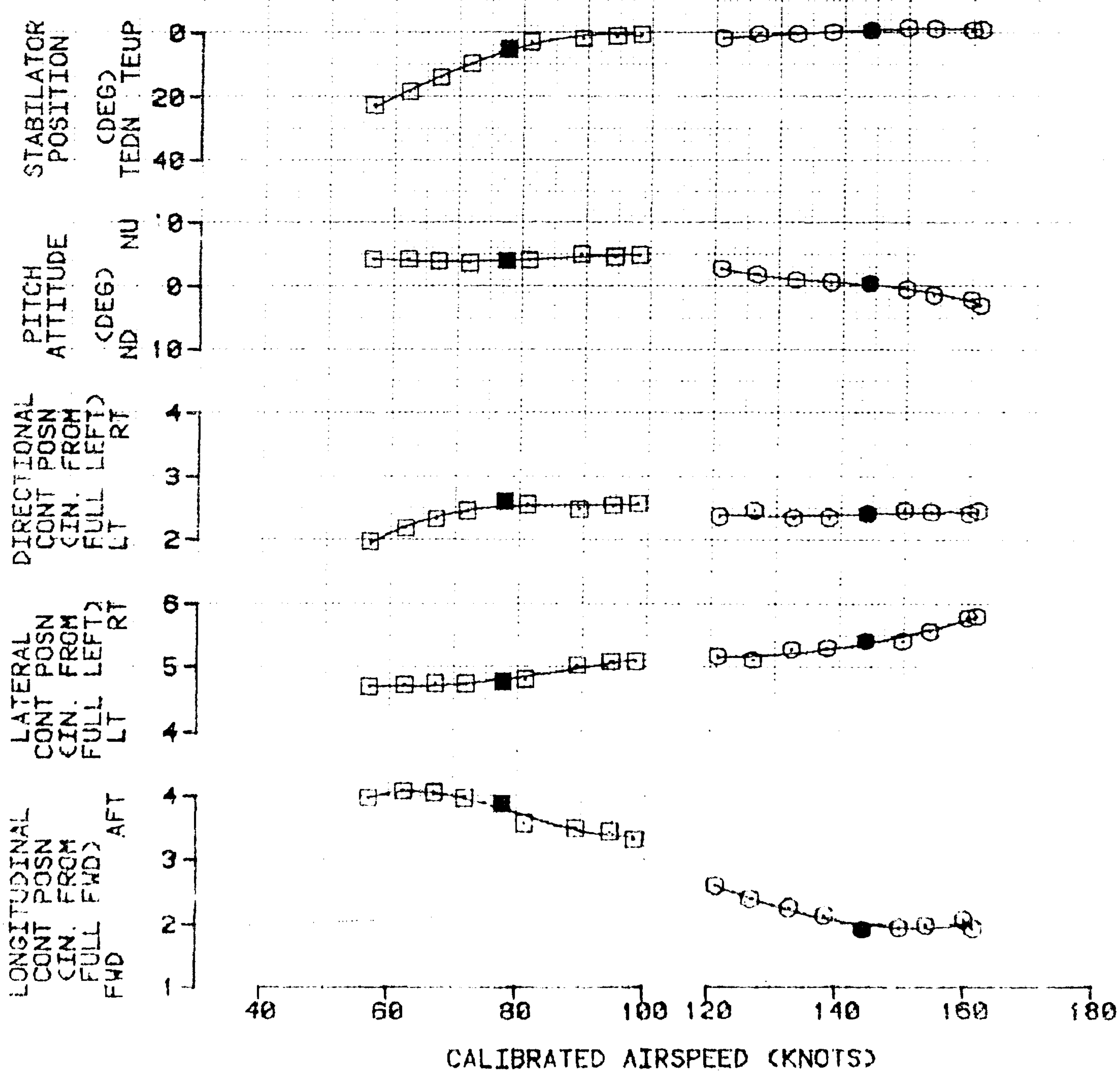


FIGURE 24

COLLECTIVE-FIXED STATIC LONGITUDINAL STABILITY

UH-60A USA S/N 77-22716

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
⊡	21880	360.4(AFT)	0.0	5740	13.0	259	LEVEL	ON
⊙	21980	360.5(AFT)	0.0	6520	16.0	260	LEVEL	ON

NOTES: 1. SHADED SYMBOLS DENOTE TRIM
2. PBA LOCKED IN CENTER POSITION
3. NORMAL UTILITY CONFIGURATION

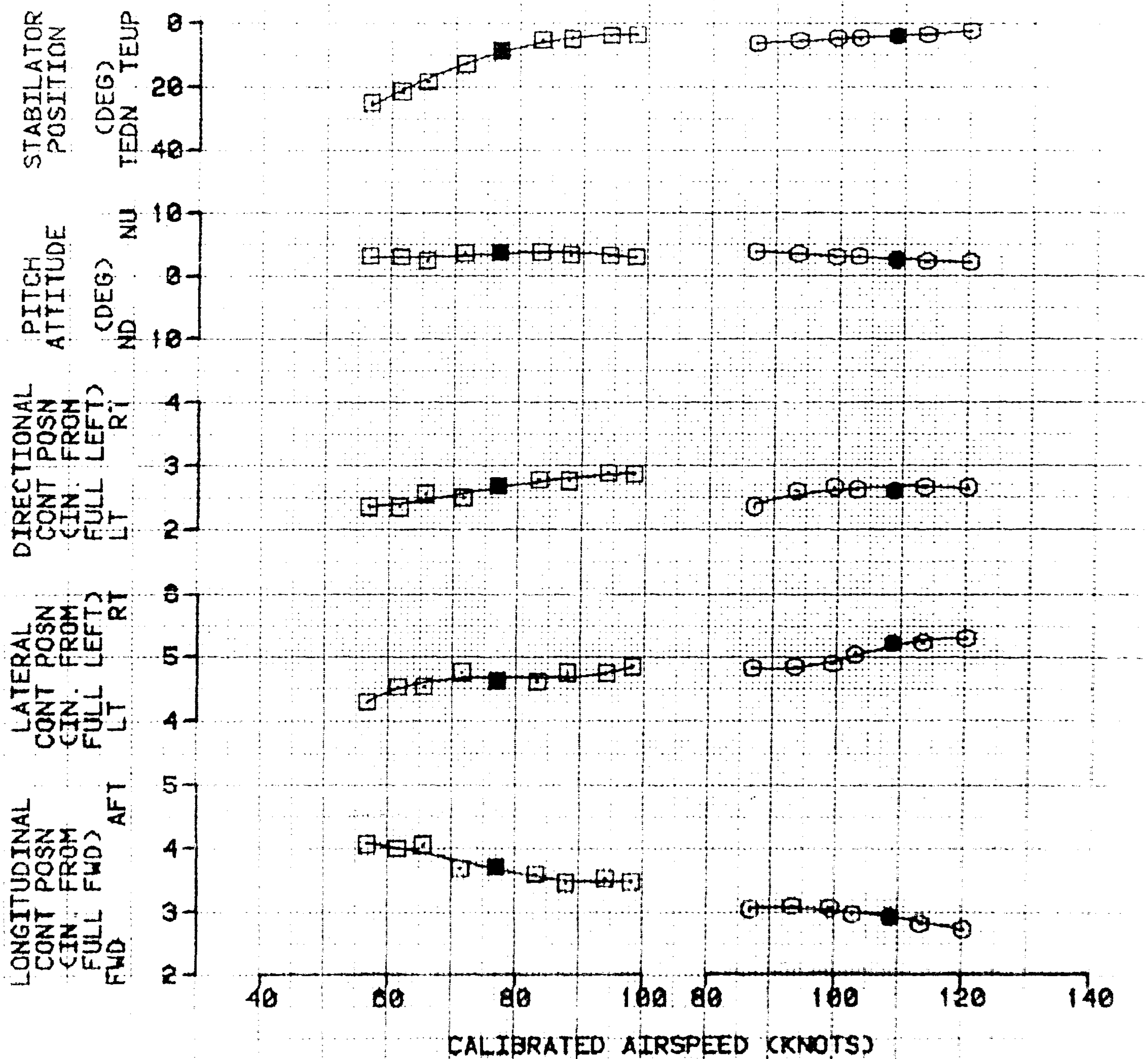


FIGURE 25

COLLECTIVE-FIXED STATIC LONGITUDINAL STABILITY

UH-60A USA S/N 77-22716

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
⊟	16600	365.1(AFT)	0.0	6940	21.5	258	TRP CLIMB	ON
⊙	16840	365.1(AFT)	0.0	7080	20.5	258	1000 FPM DSCNT	ON

NOTES: 1. SHADED SYMBOLS DENOTE TRIM
2. NORMAL UTILITY CONFIGURATION

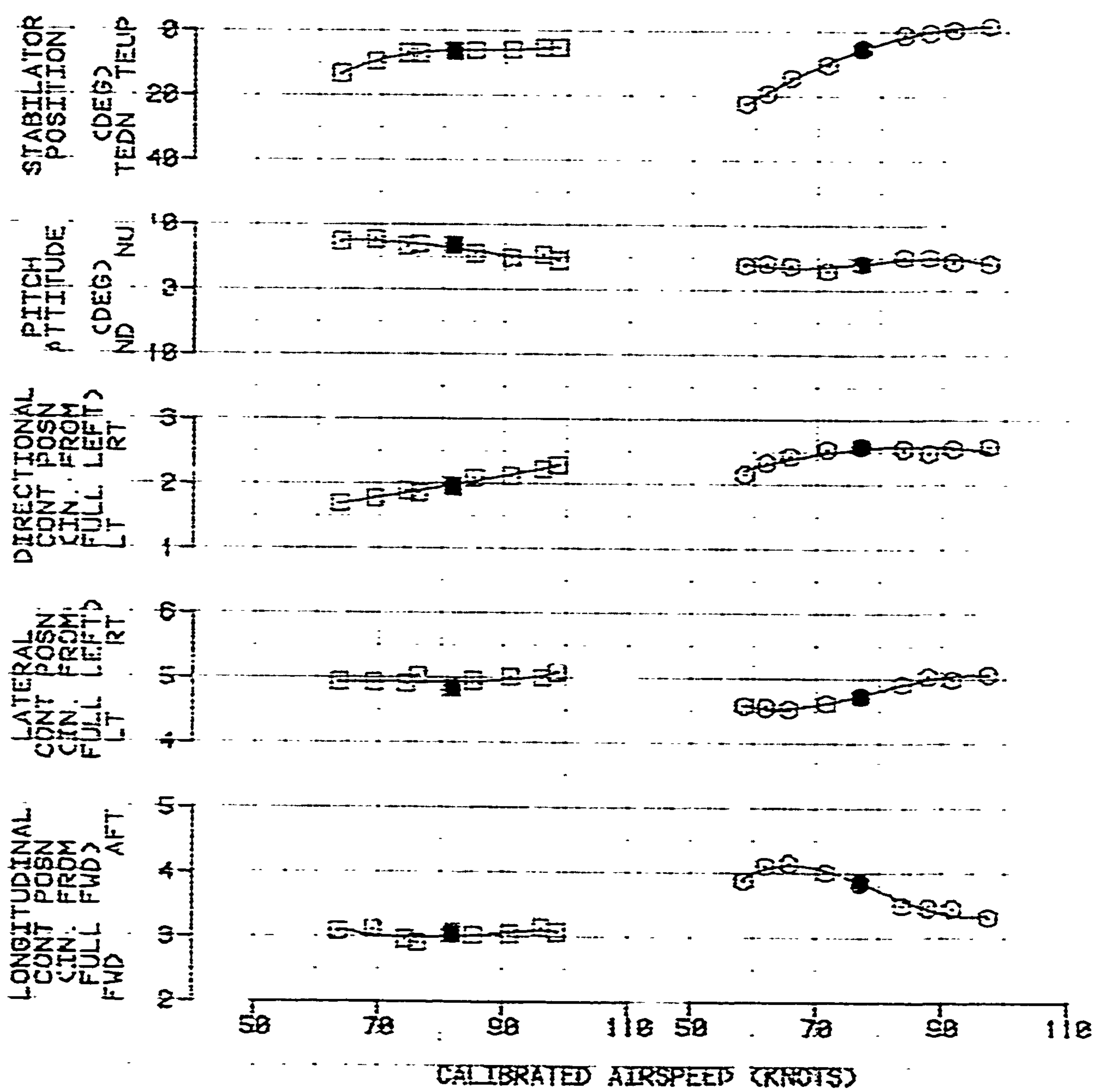


FIGURE 26

COLLECTIVE-FIXED STATIC LONGITUDINAL STABILITY

UH-60A USA S/N 77-22716

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
□	21480	360.5(AFT)	0.0	6440	12.0	257	IRP CLIMB	ON
○	21420	360.5(AFT)	0.0	5740	13.0	259	1200 FPM DSCNT	ON

NOTES: 1. SHADED SYMBOLS DENOTE TRIM

2. PBA LOCKED IN CENTER POSITION

3. NORMAL UTILITY CONFIGURATION

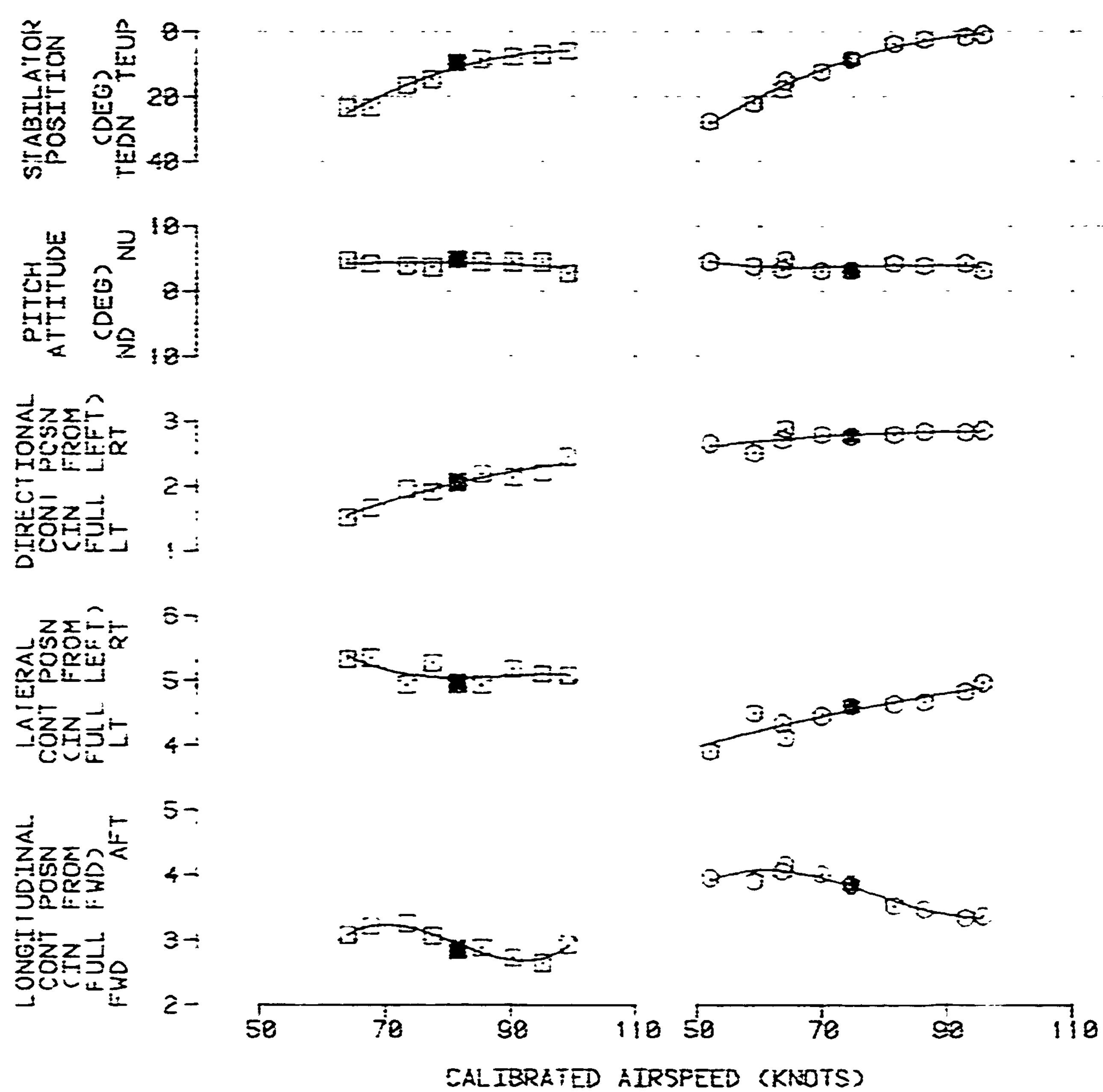


FIGURE 27

STATIC LATERAL-DIRECTIONAL STABILITY

UH-60A USA S/N 77-22716

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	AFCS CONDITION
□	17060	365.5(AFT)	0.0	5740	26.5	258	78	ON
○	16840	364.8(AFT)	0.0	6600	27.0	258	141	ON

NOTES: 1. TRIM FLIGHT CONDITION: LEVEL
2. SHADED SYMBOLS DENOTE TRIM
3. NORMAL UTILITY CONFIGURATION

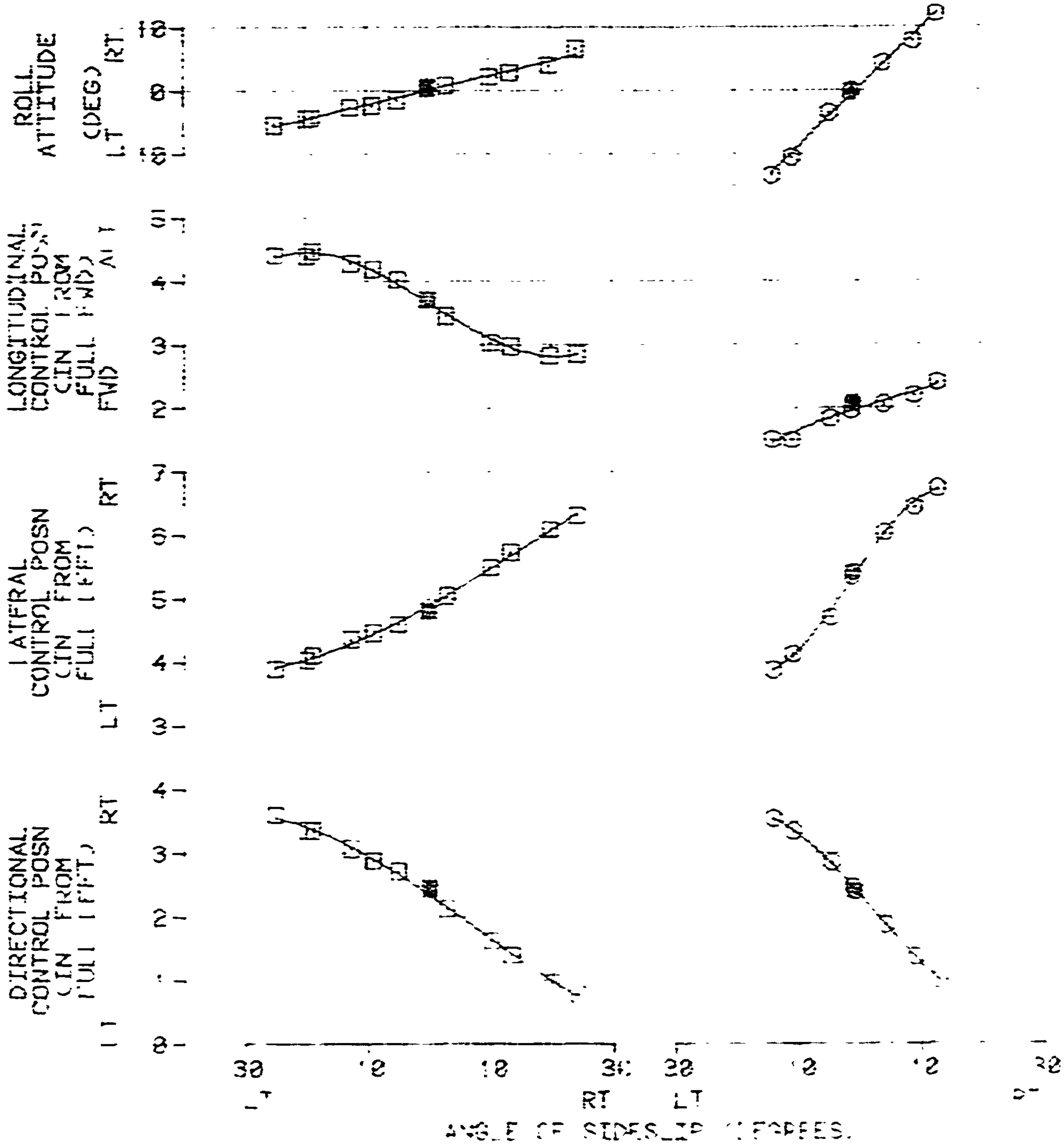


FIGURE 28

STATIC LATERAL-DIRECTIONAL STABILITY

UH-60A USA S/N 77-22716

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	AFCS CONDITION
□	21300	360.3(AFT)	0.0	6300	16.0	260	76	ON
○	21960	360.3(AFT)	0.0	6280	16.0	258	121	ON

NOTES:
1. TRIM FLIGHT CONDITION: LEVEL
2. SHADED SYMBOLS DENOTE TRIM
3. PBA LOCKED IN CENTER POSITION
4. NORMAL UTILITY CONFIGURATION

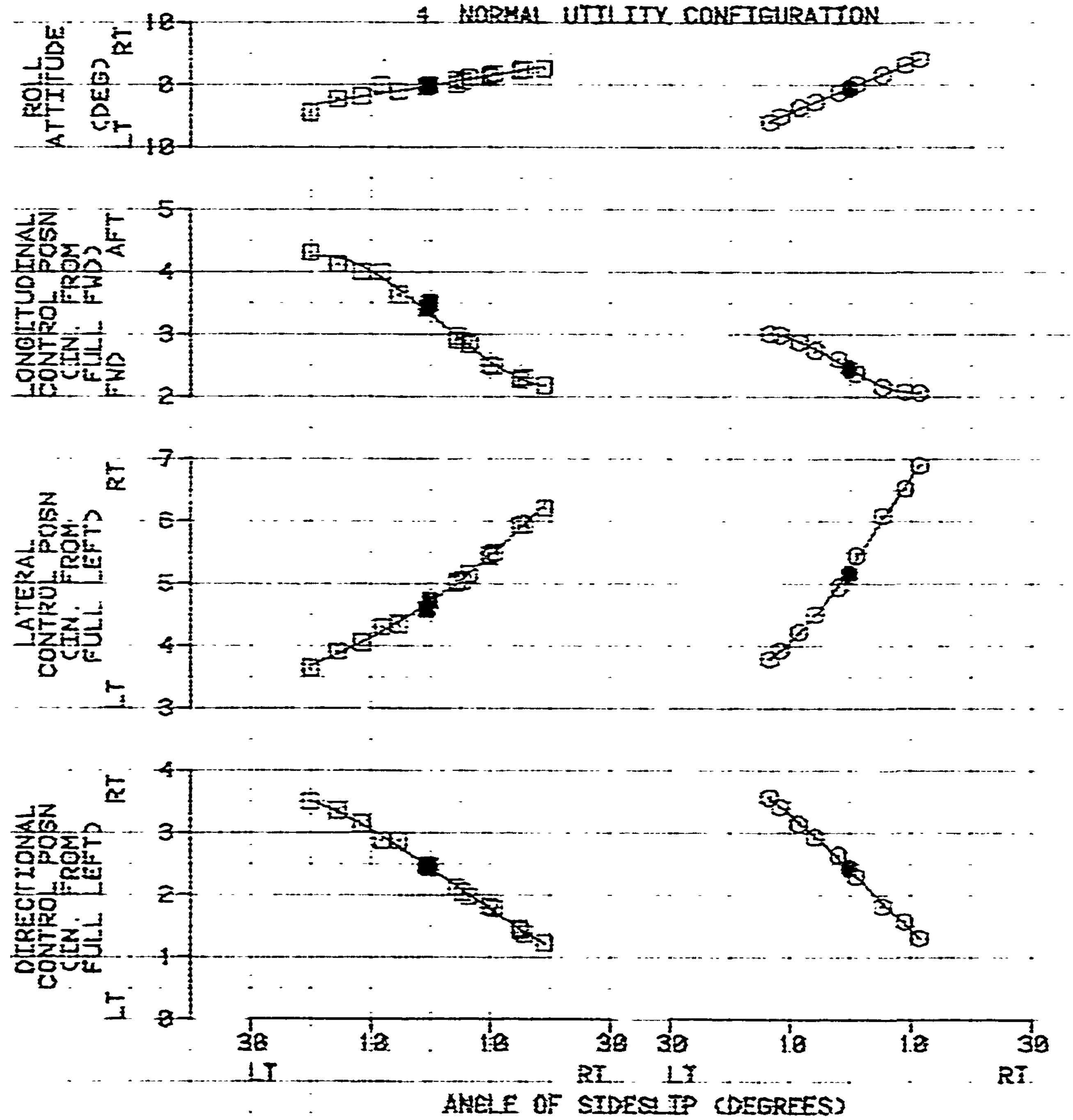


FIGURE 29

STATIC LATERAL-DIRECTIONAL STABILITY

UH-60A USA S/N 77-22716

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	AFCS CONDITION
⊡	16720	366.5(AFT)	0.0	7120	24.5	258	83	ON
⊙	16540	365.8(AFT)	0.2	6580	22.0	258	77	ON

NOTES: 1. ⊡ DENOTES IF? CLIMB
⊙ DENOTES 10L3 FPM DESCENT
2. SHADED SYMBOLS DENOTE TRIM
3. NORMAL UTILITY CONFIGURATION

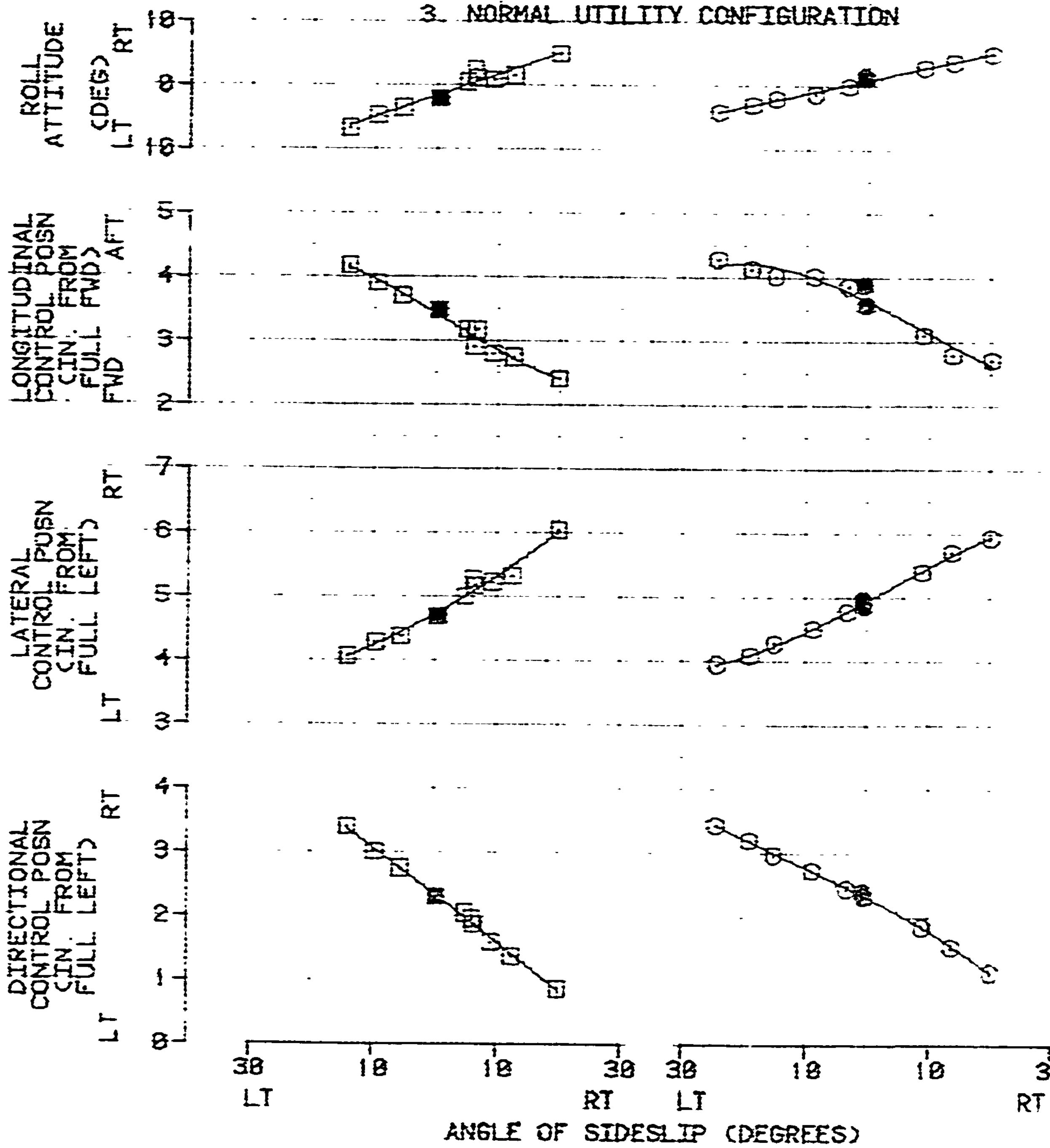


FIGURE 30

STATIC LATERAL-DIRECTIONAL STABILITY

UH-60A USA S/N 77-22716

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	AFCS CONDITION
□	21700	360.4(AFT)	0.0	5920	8.0	258	81	ON
○	21040	360.3(AFT)	0.0	5660	10.0	258	77	ON

NOTES: 1. □ DENOTES IRP CLIMB
○ DENOTES 1000 FPM DESCENT
2. SHADED SYMBOLS DENOTE TRIM
3. PBA LOCKED IN CENTER POSITION
4. NORMAL UTILITY CONFIGURATION

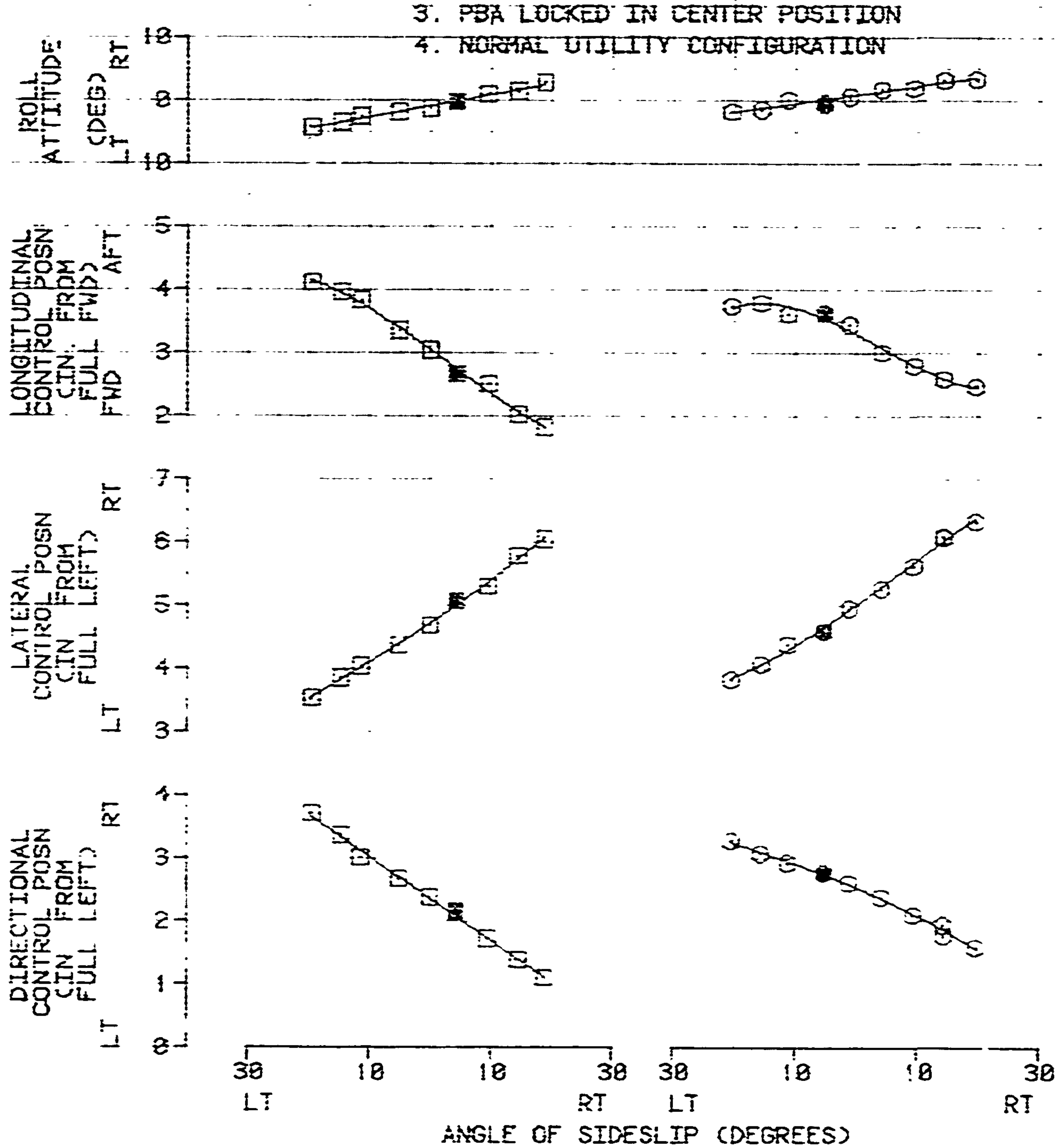


FIGURE 31
MANEUVERING STABILITY
UH-60A USA S/N 77-22716

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	TRIM CALIBRATED AIRSPEED (KT)
⊡	16580	365.0(AFT)	0.0	6440	17.0	260	LEVEL	77
⊙	16720	365.1(AFT)	0.0	7320	17.0	258	LEVEL	141

NOTES: 1. OPENED SYMBOLS DENOTE LEFT TURN
CROSSED SYMBOLS DENOTE RIGHT TURN
2. SHADED SYMBOLS DENOTE TRIM
3. AFCS CONDITION: ON
4. NORMAL UTILITY CONFIGURATION

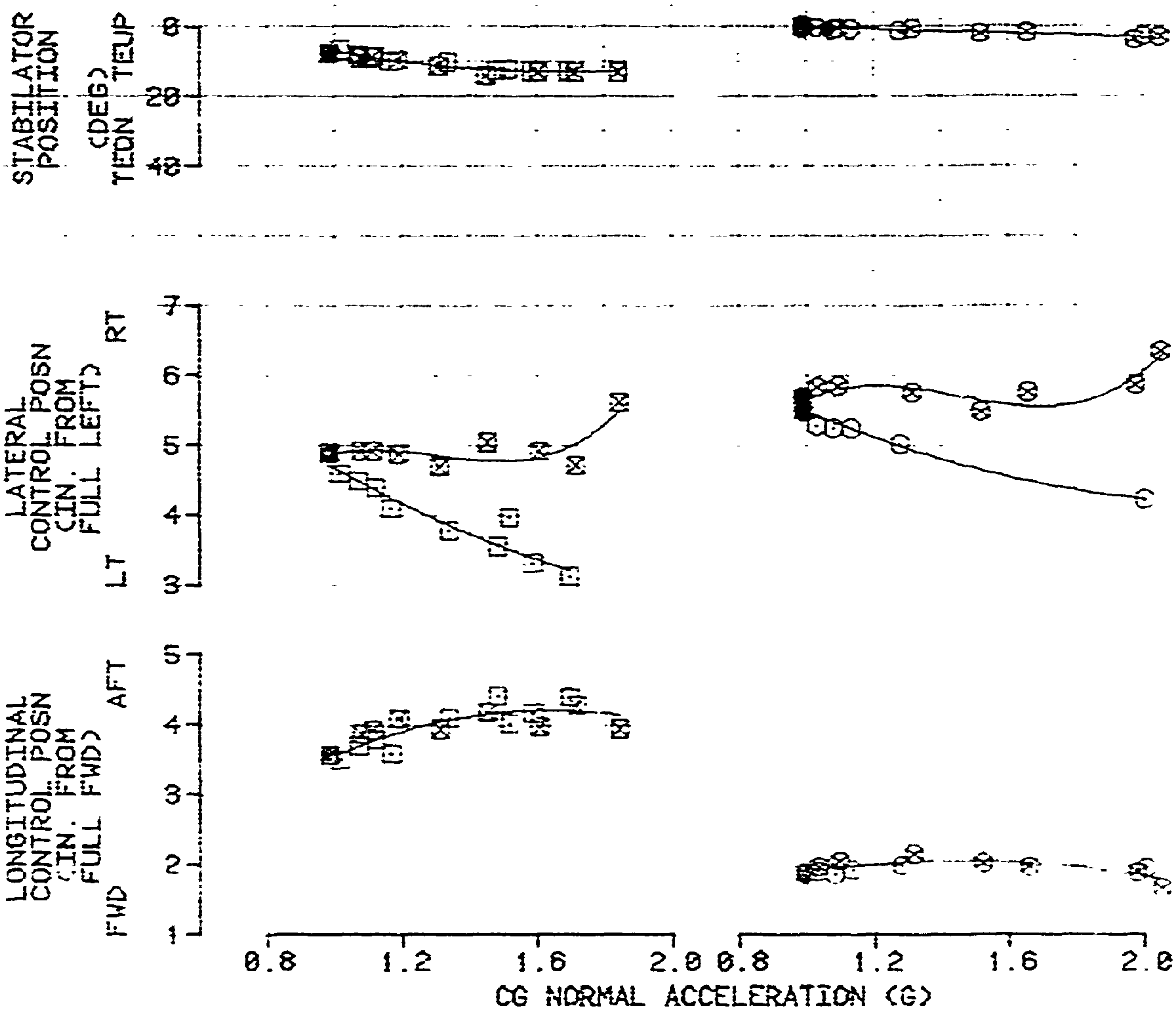


FIGURE 32

MANEUVERING STABILITY

UH-60A USA S/N 77-22716

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	TRIM CALIBRATED AIRSPEED (KT)
⊡	21400	360.3(AFT)	0.0	6560	15.5	261	LEVEL	77
⊙	20860	360.4(AFT)	0.0	6740	15.0	260	LEVEL	107

NOTES: 1. OPENED SYMBOLS DENOTE LEFT TURN
CROSSED SYMBOLS DENOTE RIGHT TURN
2. SHADED SYMBOLS DENOTE TRIM
3. AFCS CONDITION: ON
4. PBA LOCKED IN CENTER POSITION
5. NORMAL UTILITY CONFIGURATION

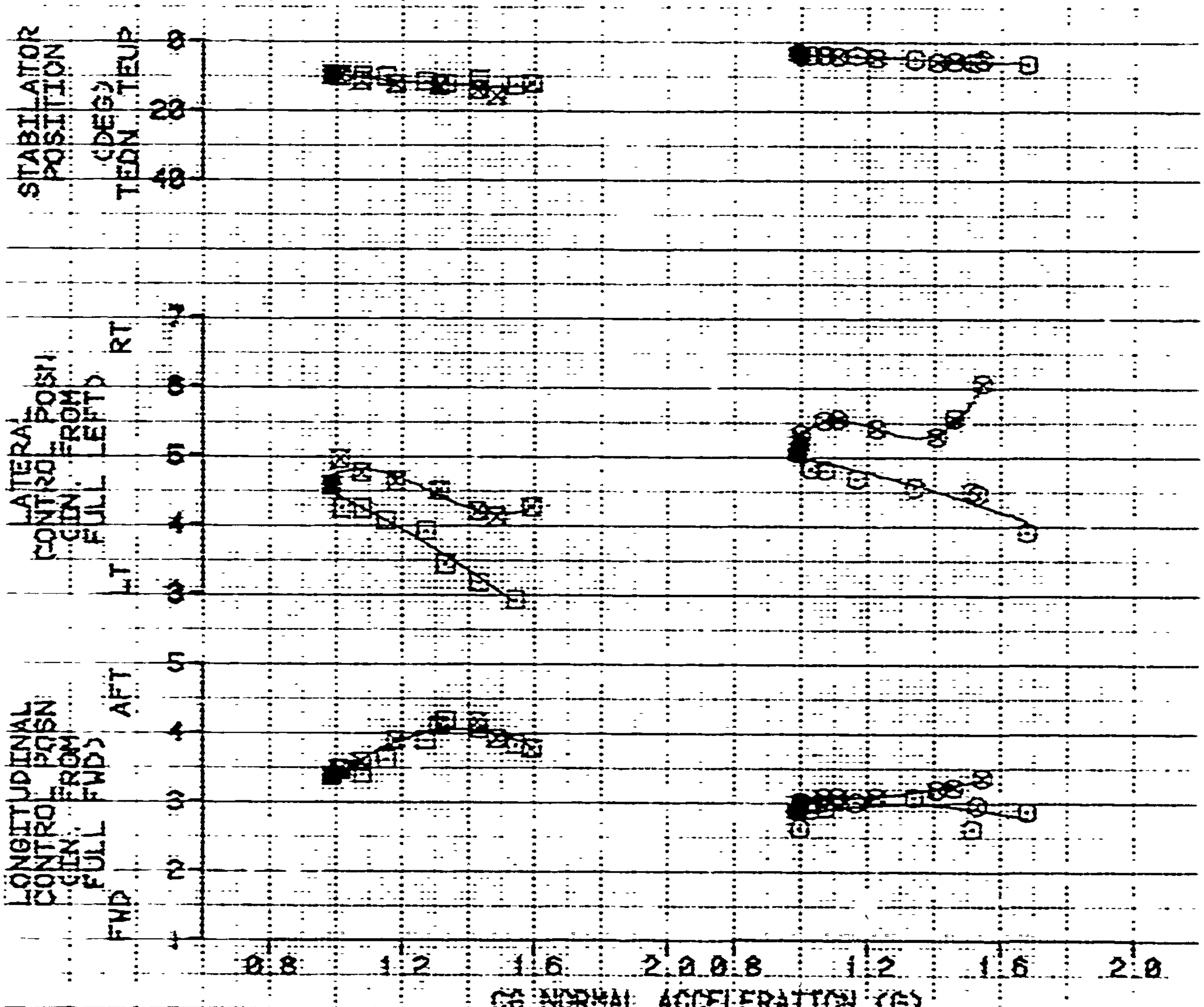


FIGURE [illegible]
MANEUVERING STABILITY
UH-60A USA S/N 77-22710

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY ROTOR SPEED (RPM)	ENTRY CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION	AFCS CONDITION
21600	300 3(AFT)	0 0	6380	16 5	257	70	LEFT TURN	ON

NOTE NORMAL UTILITY CONFIGURATION

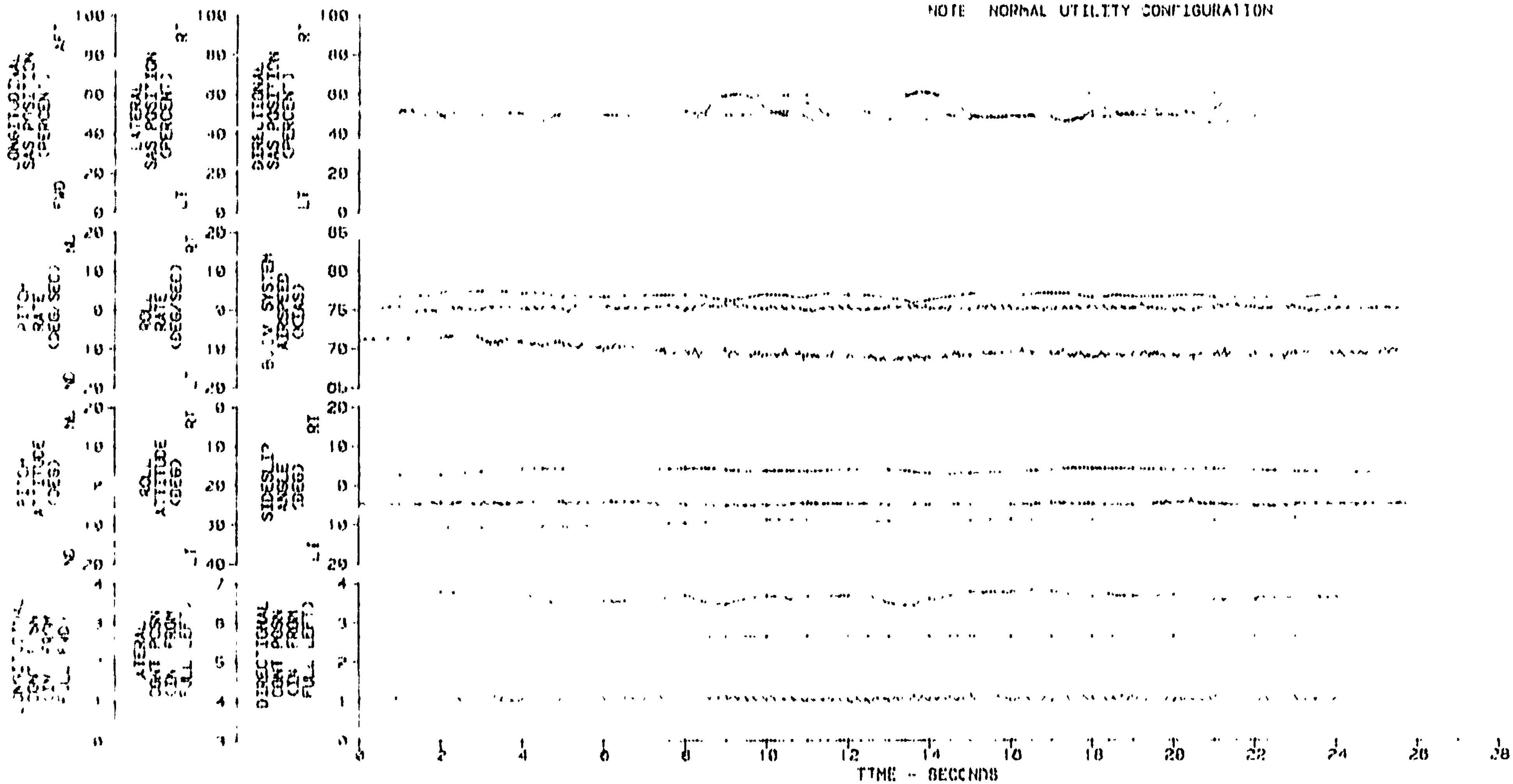


FIGURE 34
MANEUVERING STABILITY
UH-60A USA S/N 77-22716

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY ROTOR SPEED (RPM)	ENTRY CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION	AFCS CONDITION
21320	360.2(AFT)	0.0	8020	14.5	258	82	LEFT TURN	ON

NOTE: NORMAL UTILITY CONFIGURATION

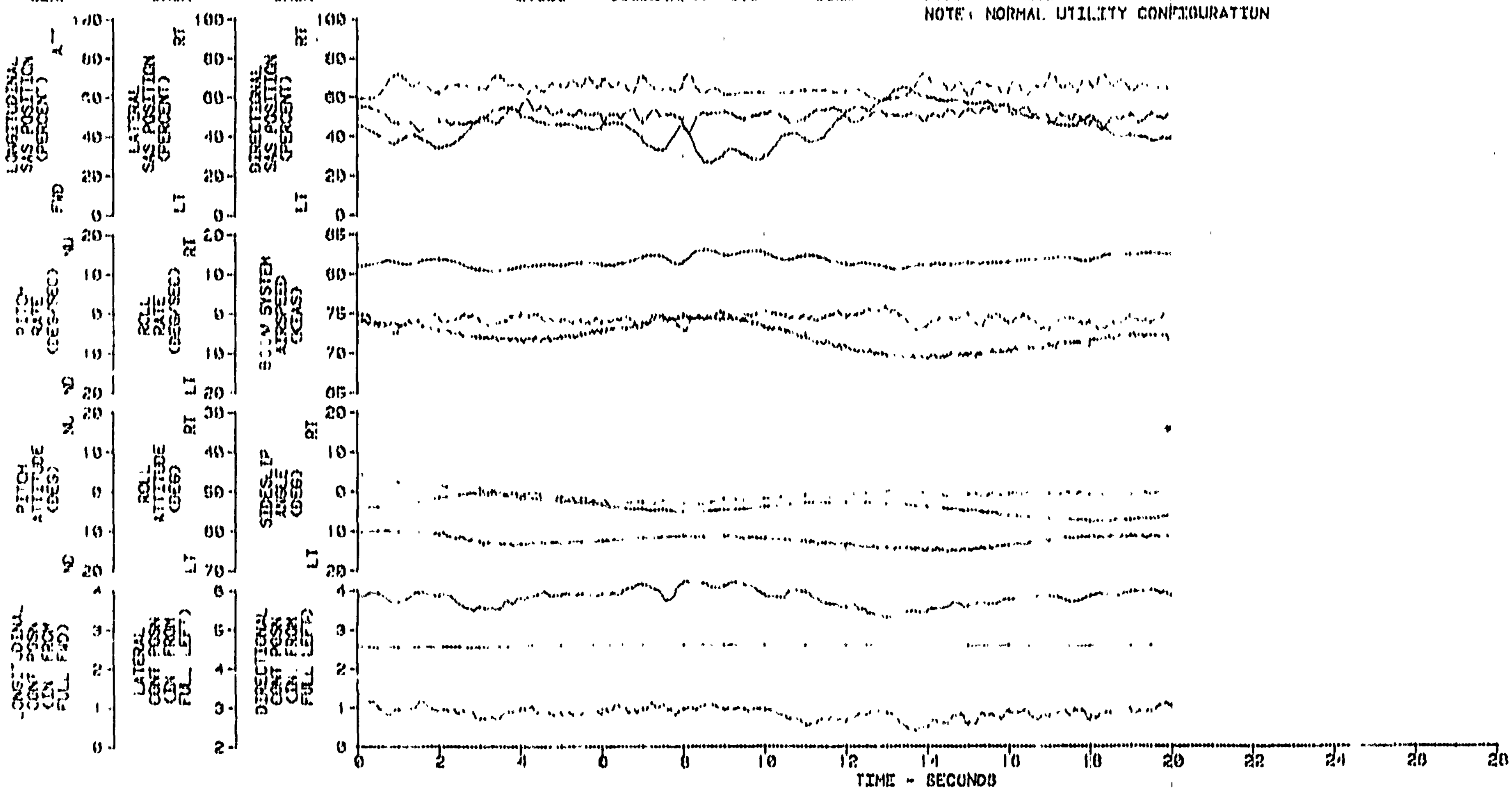


FIGURE [illegible]

MANEUVERING STABILITY

UH-60 USA S/N 77-22710

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY ROTOR SPEED (RPM)	ENTRY CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION	AFCS CONDITION
21200	360.4(AFT)	0.0	6440	10.0	258	111	LEFT TURN	ON

NOTE: NORMAL UTILITY CONFIGURATION

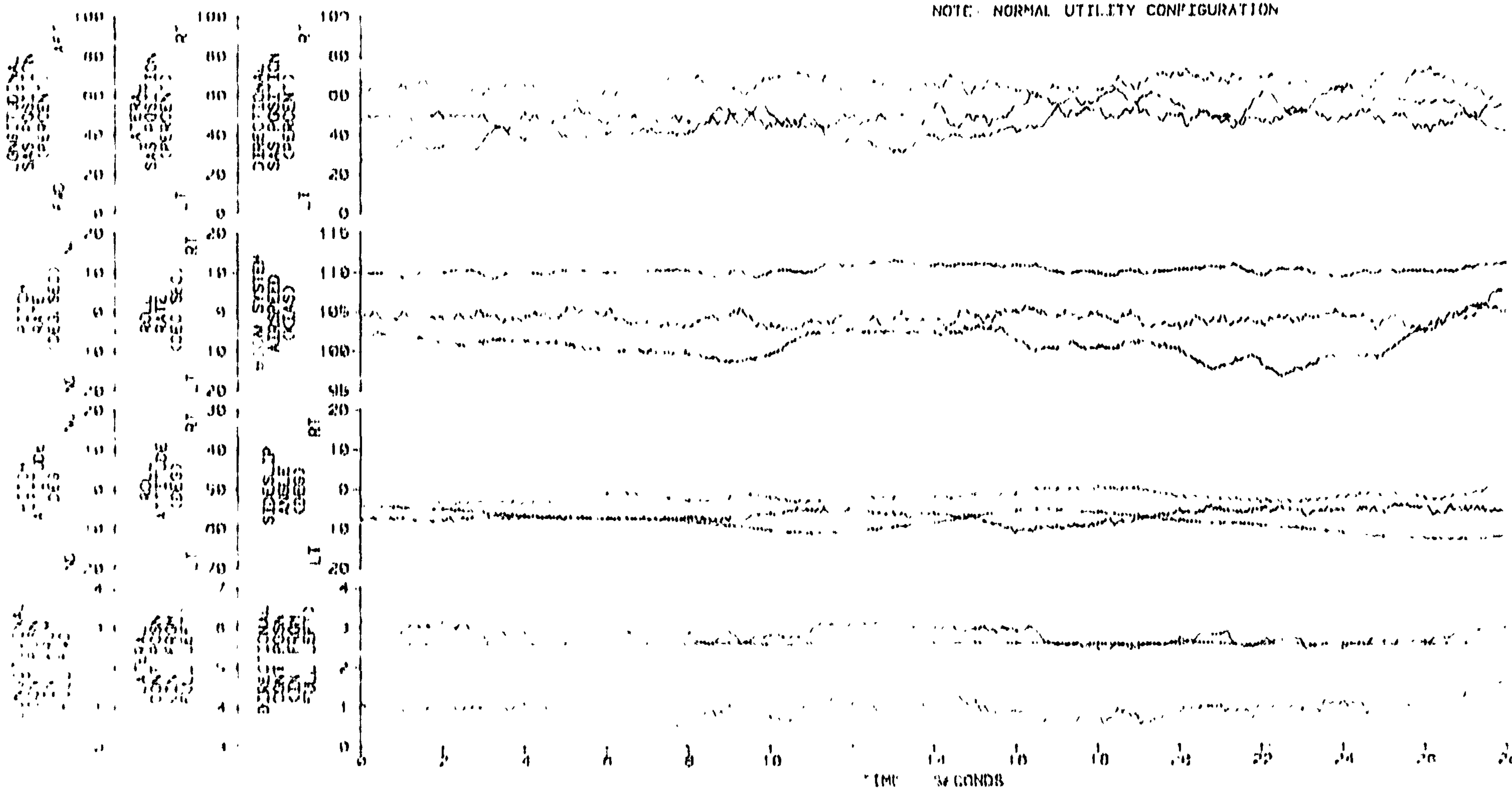


FIGURE 30
LONGITUDINAL PULSE
UH-60A USA S/N 77-22716

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (DEG C)	MAIN ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION	AFCS CONDITION
21400	300.4(AFT)	0.0	5600	8.5	259	111	LEVEL	ON

NOTE: NORMAL UTILITY CONFIGURATION

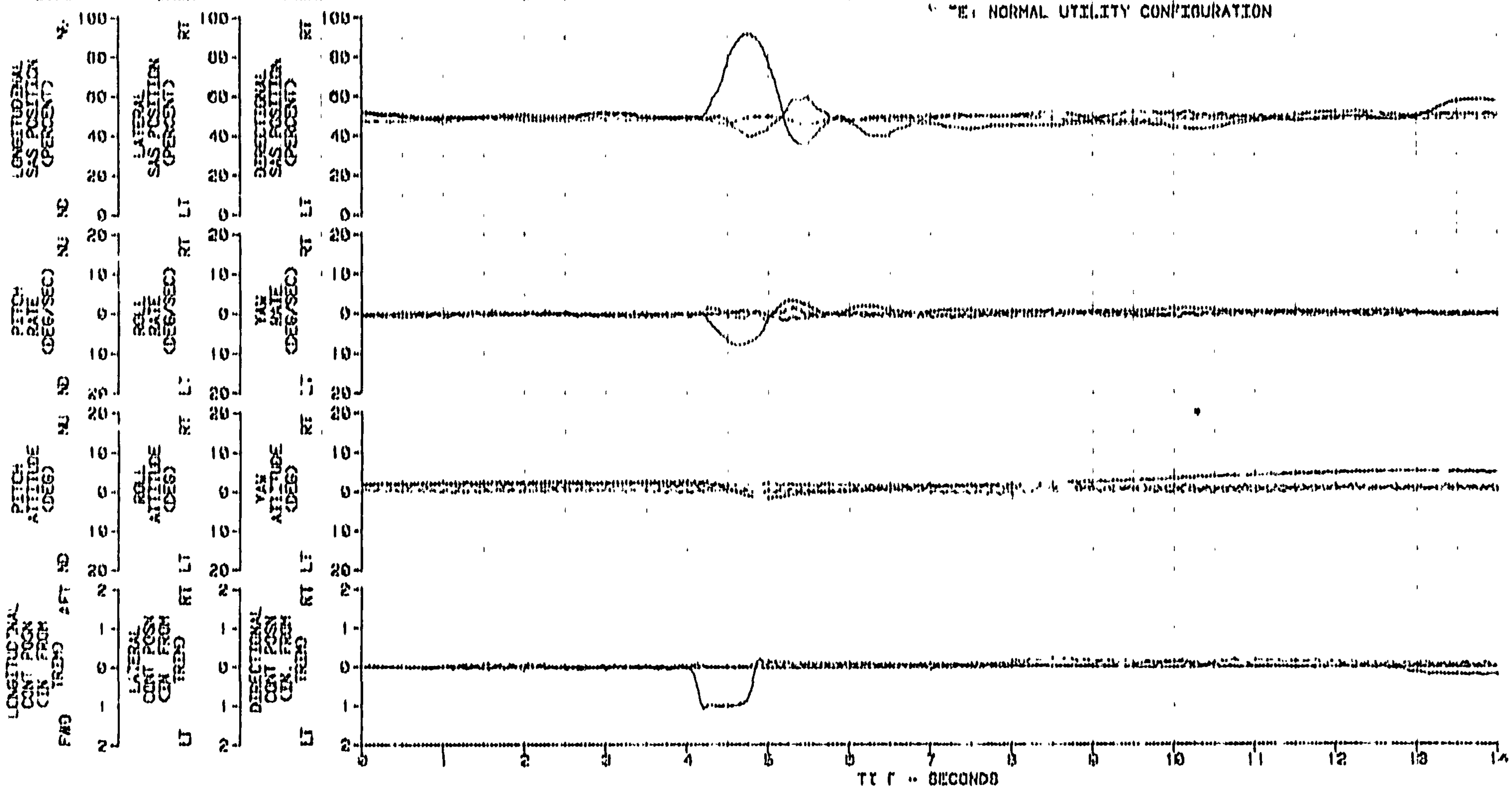


FIGURE 37

LATERAL PULSE

UH-60A USA S/N 77-22716

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (DEG C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION	AFCS CONDITION
21540	360 3(AFT)	0 0	5000	10 0	260	110	LEVEL	ON

NOTE: NORMAL UTILITY CONFIGURATION

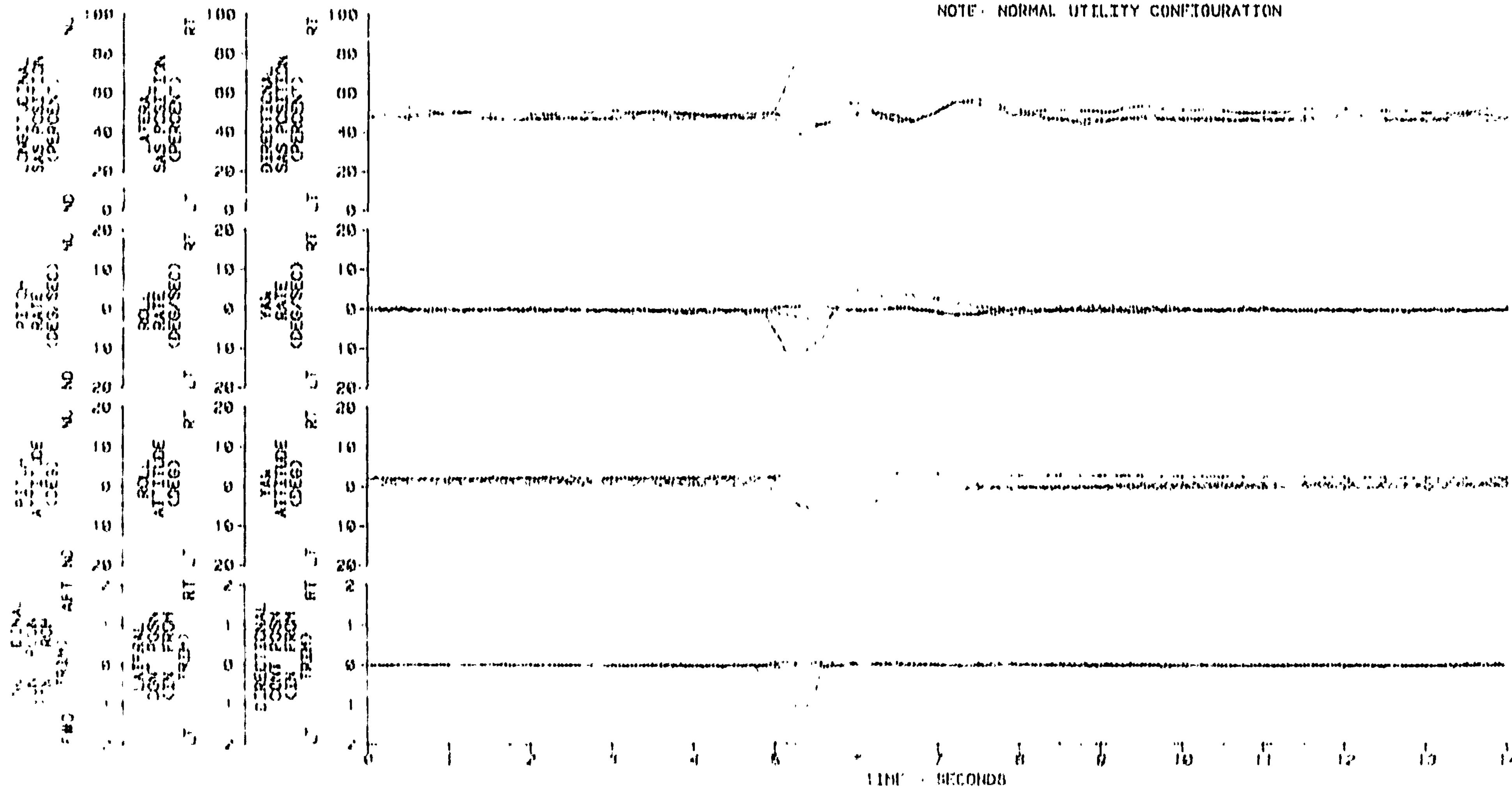


FIGURE 38
DIRECTIONAL PULSE
UH-60A USA S/N 77-22716

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (DEG C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION	AFCS CONDITION
21000	300.1(AFT)	0.0	5000	8.5	258	110	LEVEL	ON

NOTE: NORMAL UTILITY CONFIGURATION

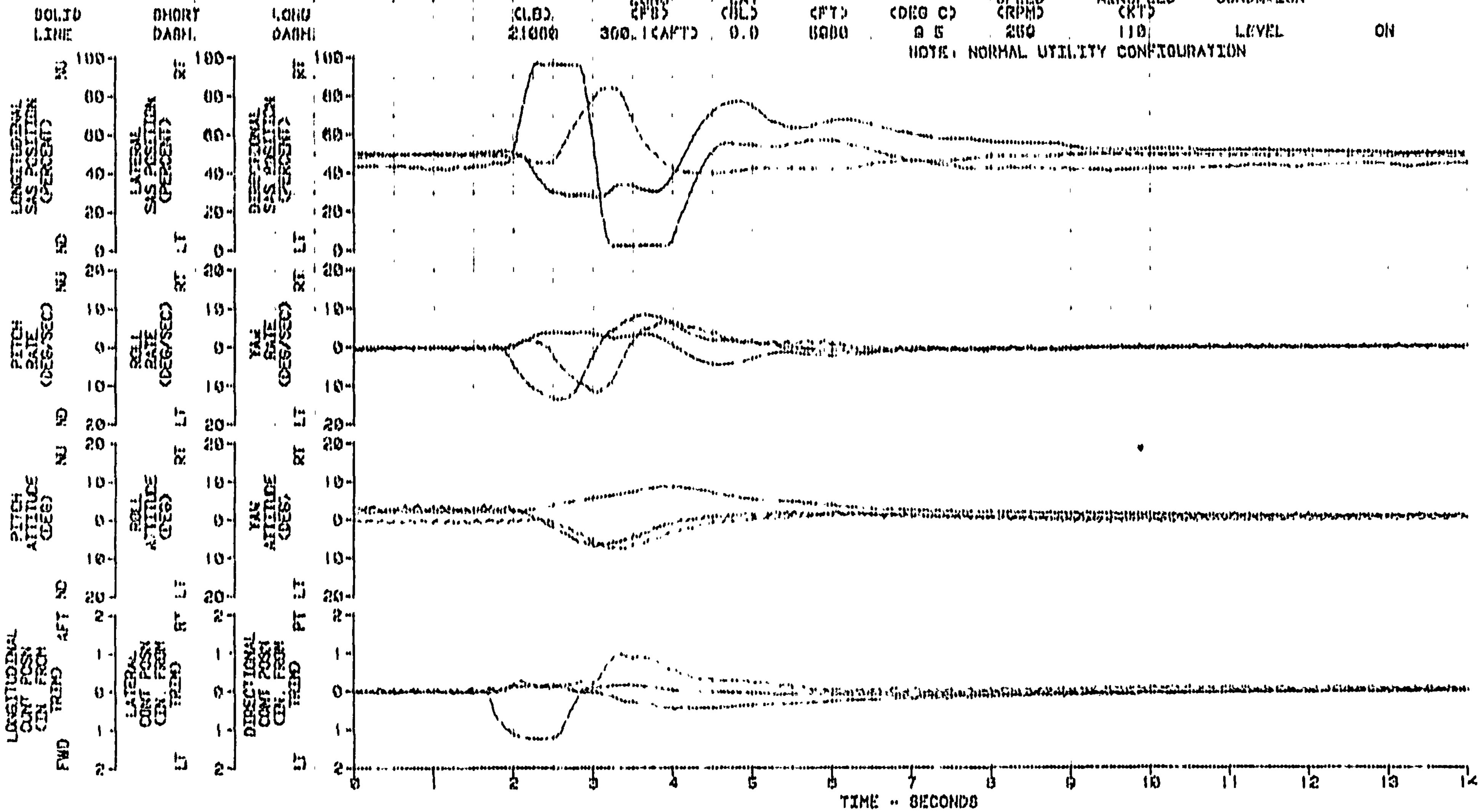


FIGURE [illegible]

RELEASE FROM STEADY SIDESLIP

UH-60A USA S/N 77 22716

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (DEG C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION	AFCS CONDITION
21700	360.3(AFT)	0.0	6400	15.5	257	122	LEVEL	ON

NOTE NORMAL UTILITY CONFIGURATION

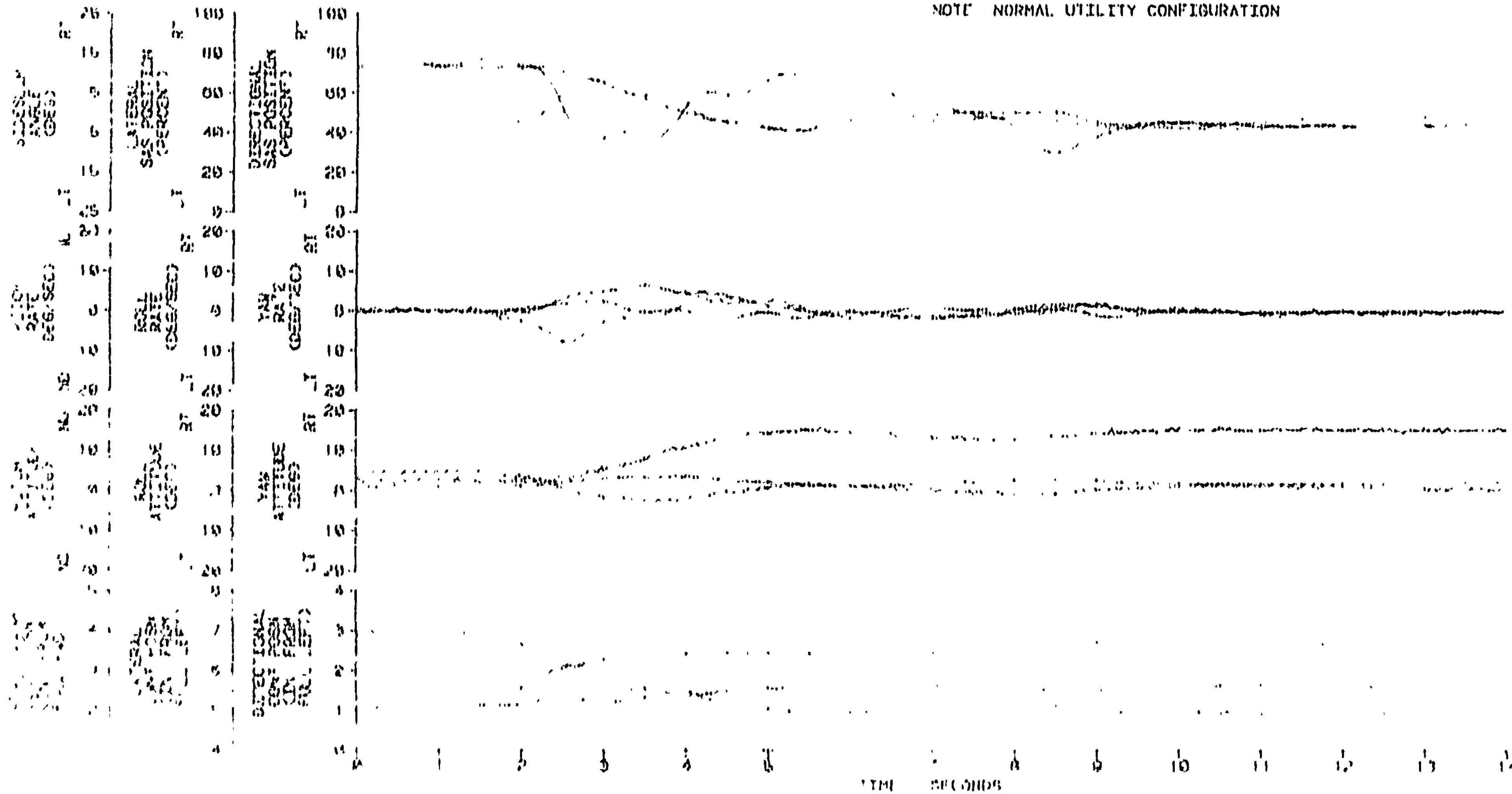


FIGURE 20

LONGITUDINAL CONTROLLABILITY

UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	AFCS CONDITION
16,900	363.6(AFT)	0.0	2300	9.5	258	0	ON

NOTE: NORMAL UTILITY CONFIGURATION

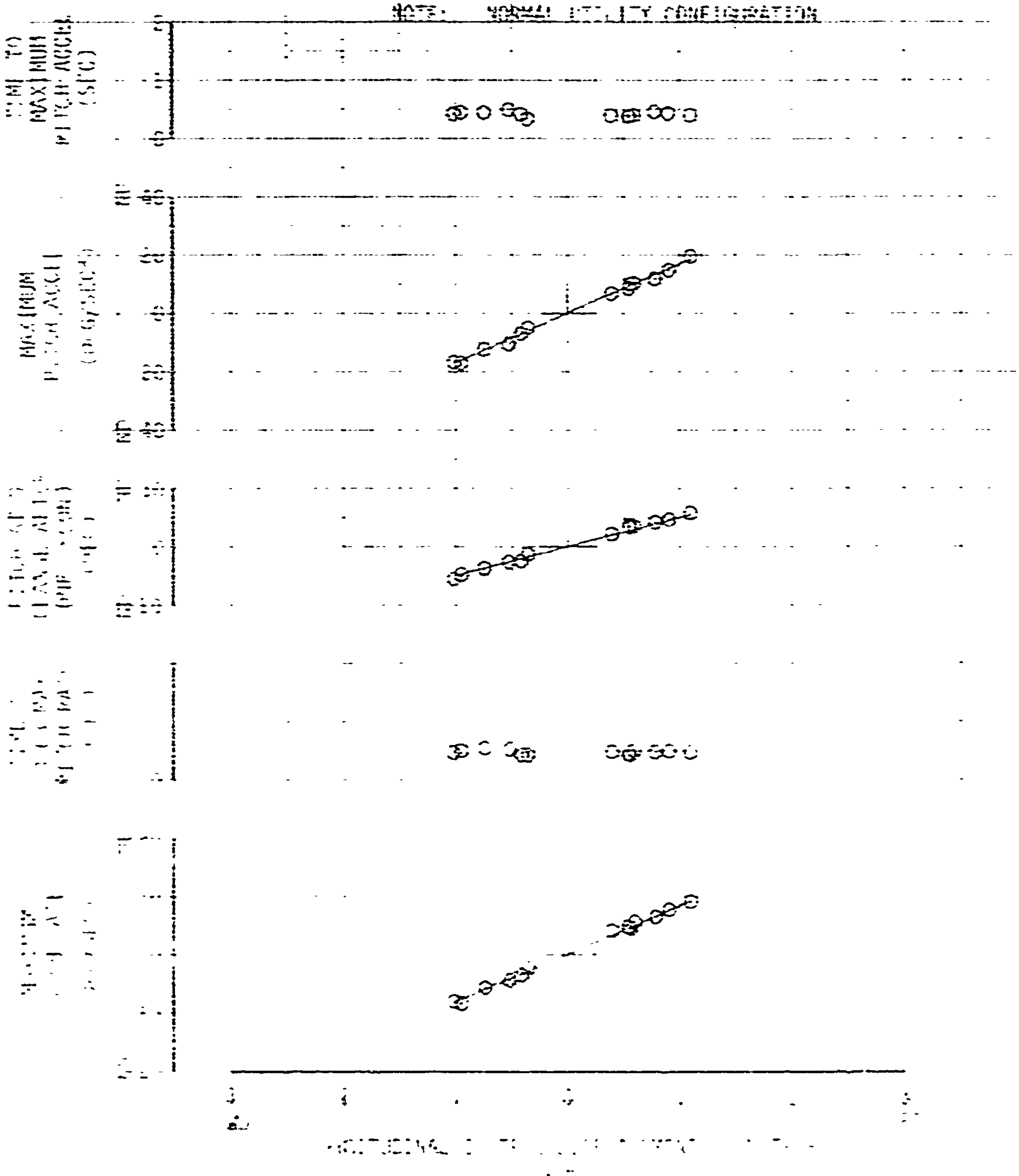


FIGURE 41

LONGITUDINAL CONTROLLABILITY

UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	AFCS CONDITION	SYM
15,840	363.7(AFT)	0.0	5100	14.0	258	80	ON	○
15,900	363.6(AFT)	0.0	5600	15.0	258	143	ON	□

NOTE: NORMAL UTILITY CONFIGURATION

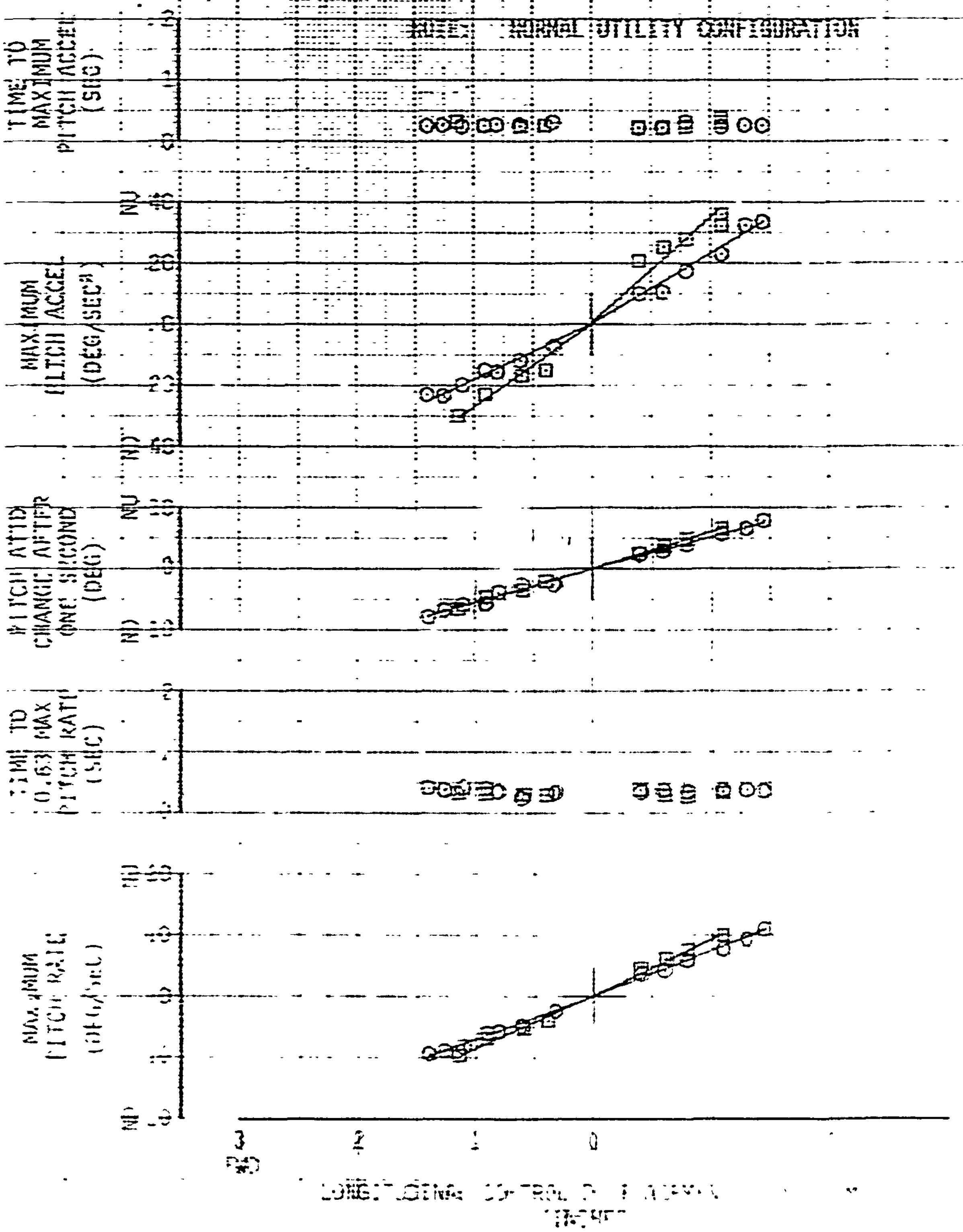


FIGURE 42
LONGITUDINAL CONTROLLABILITY
UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	AFCS CONDITION	SYM
22,000	360.4(AFT)	0.0	6000	15.5	258	78	ON	○
21,900	360.2(AFT)	0.0	5900	9.5	258	109	ON	□

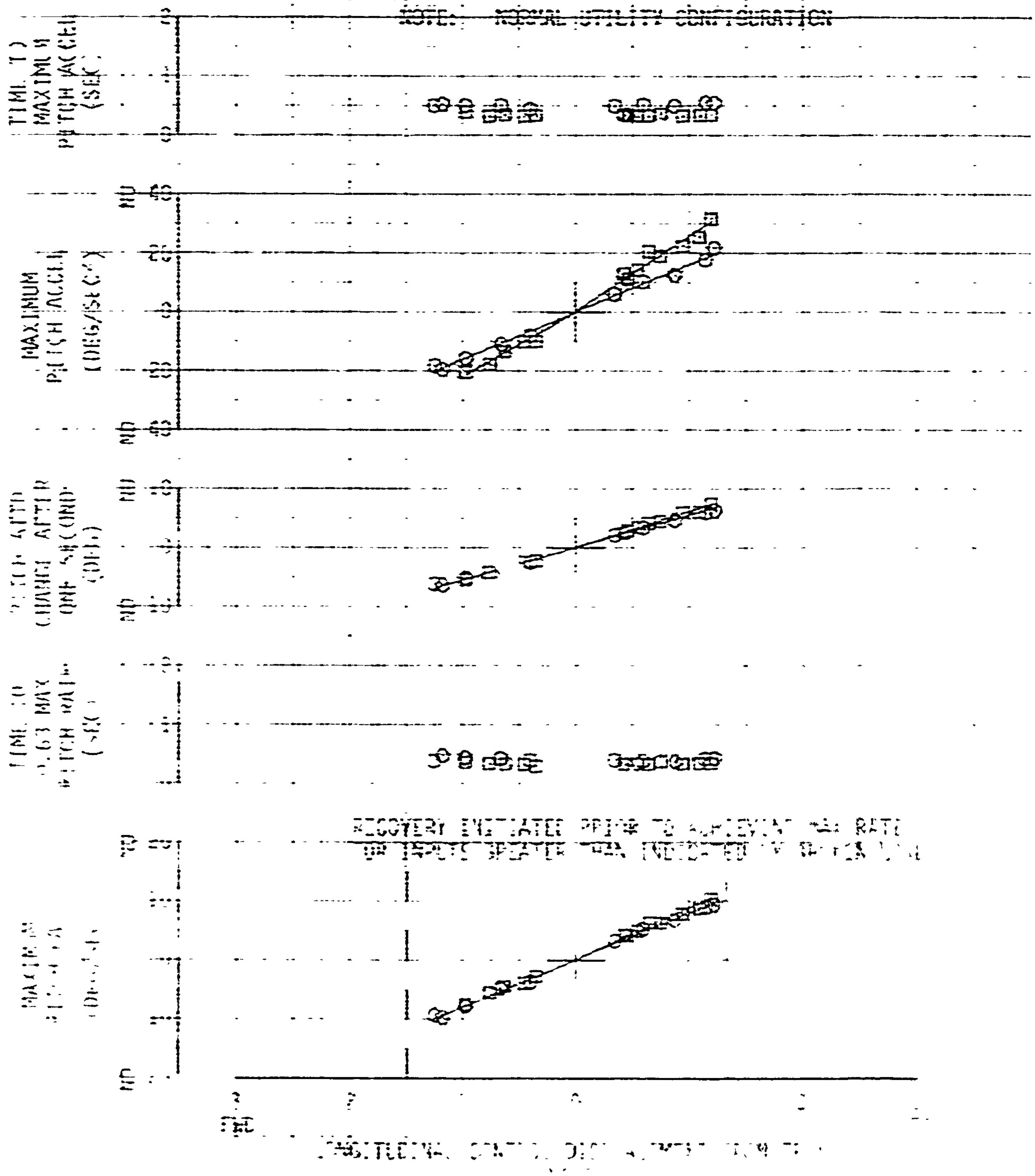


FIGURE 43
LONGITUDINAL STEP
UH-60A USA S/N 77-22716

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (DEG C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION	AFCS CONDITION
16000	384.0(AFT)	0.0	6320	14.6	258	130	LEVEL	ON

NOTE: NORMAL UTILITY CONFIGURATION

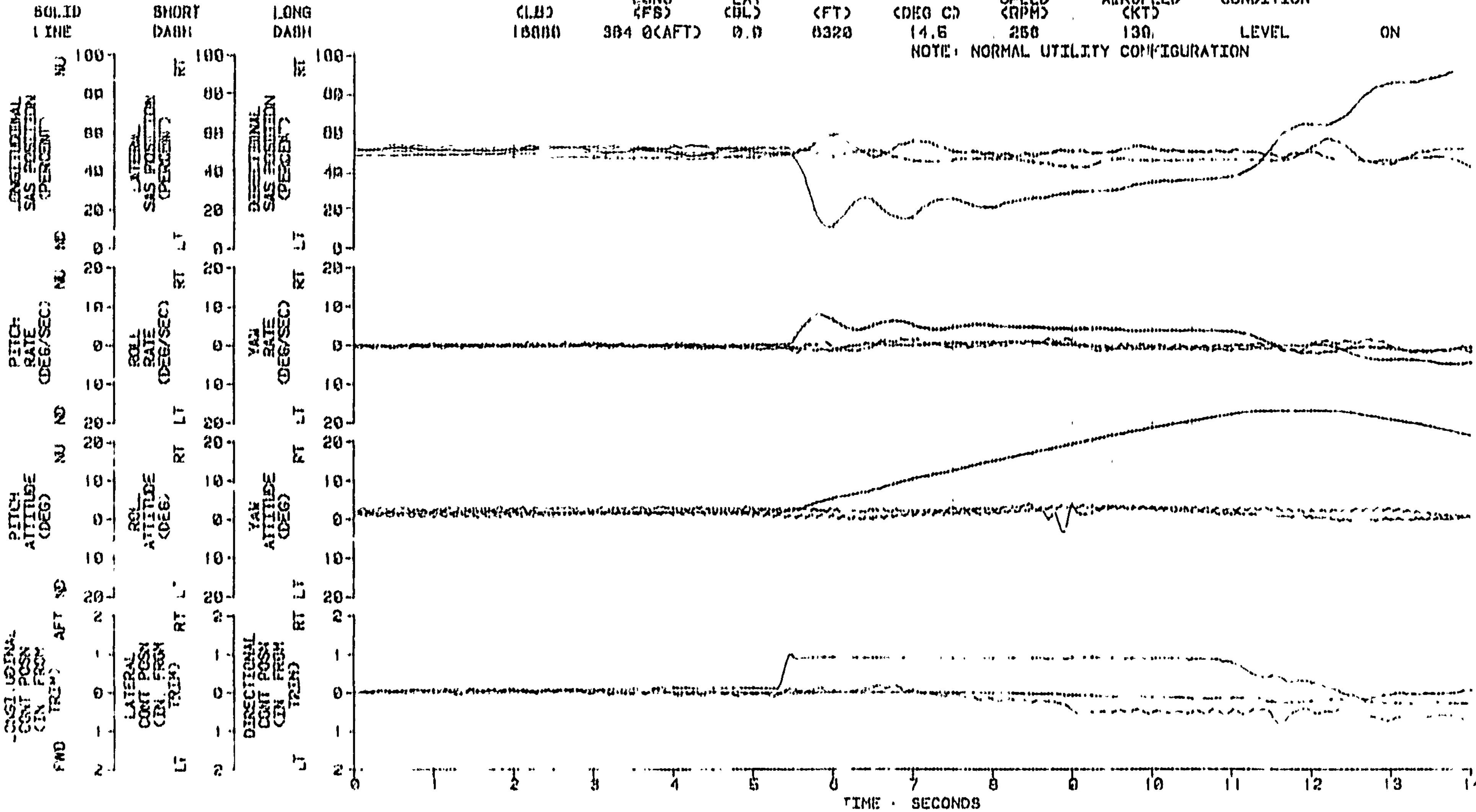


FIGURE 44
LONGITUDINAL STEP
UH-60A USA S/N 77-22716

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (DEG C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION	AFCS CONDITION
21700	300.2(AFT)	0.0	5000	0.5	258	100	LEVEL	ON

NOTE: NORMAL UTILITY CONFIGURATION

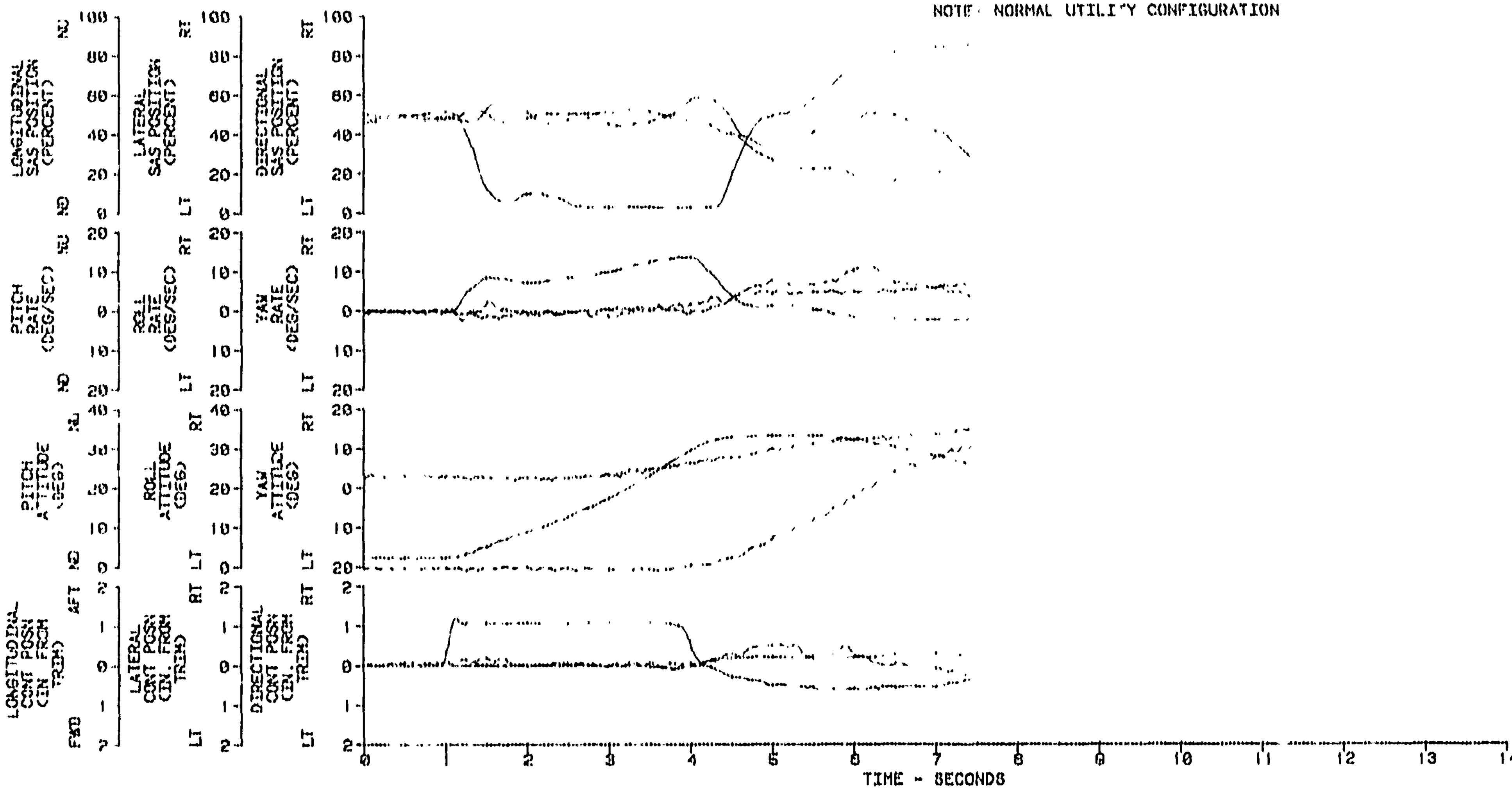


FIGURE 46
LONGITUDINAL STEP
UH-60A USA S/N 77-22716

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (DEG C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION	AFCS CONDITION
21500	300.0(AFT)	0.0	5000	10.0	258	78	LEVEL	ON

NOTE: NORMAL UTILITY CONFIGURATION

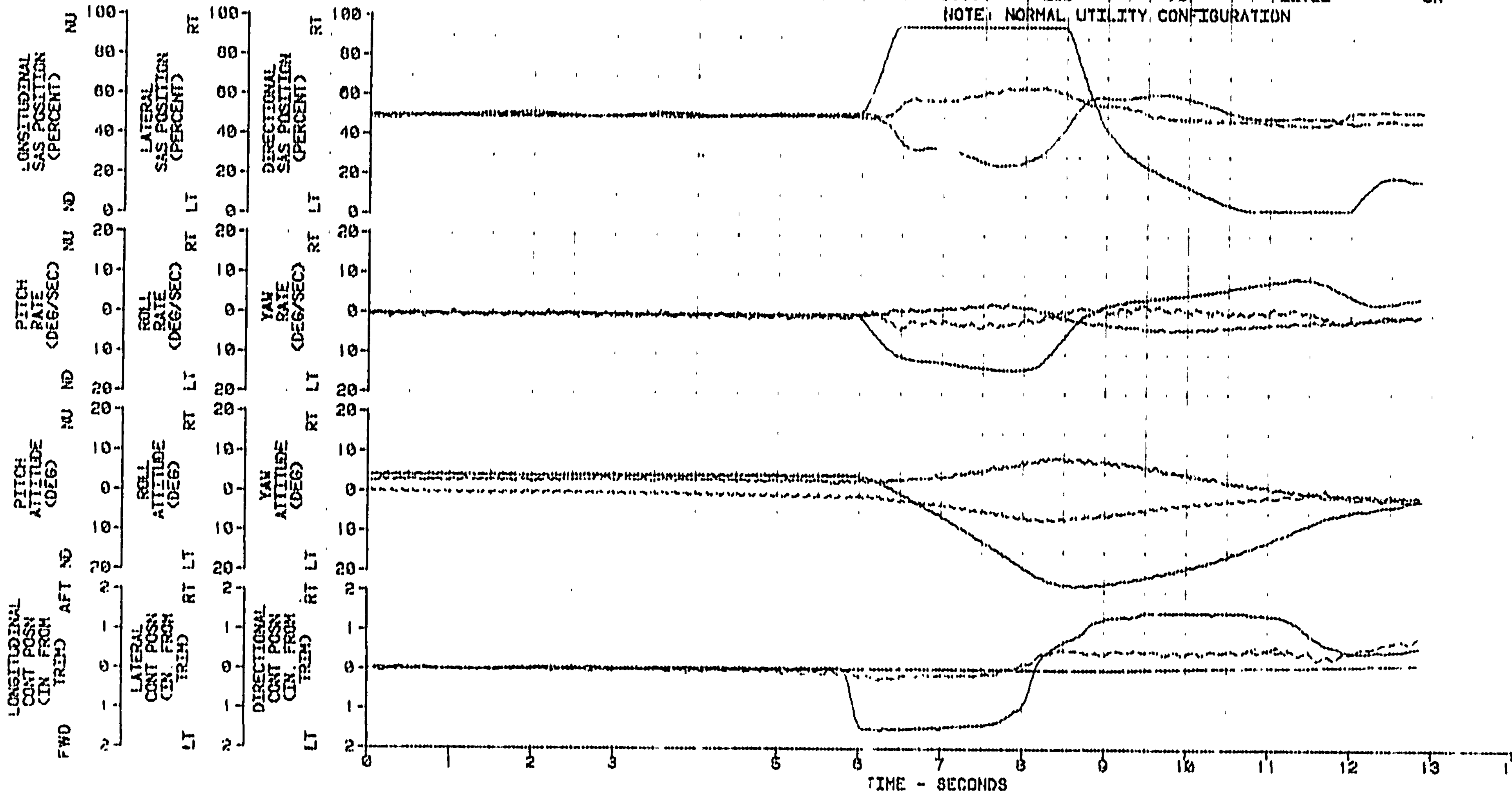


FIGURE 46
LATERAL CONTROLLABILITY
UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	AFCS CONDITION
16,660	363.6(AFT)	0.0	2380	9.5	258	0	ON

NOTE: NORMAL UTILITY CONFIGURATION

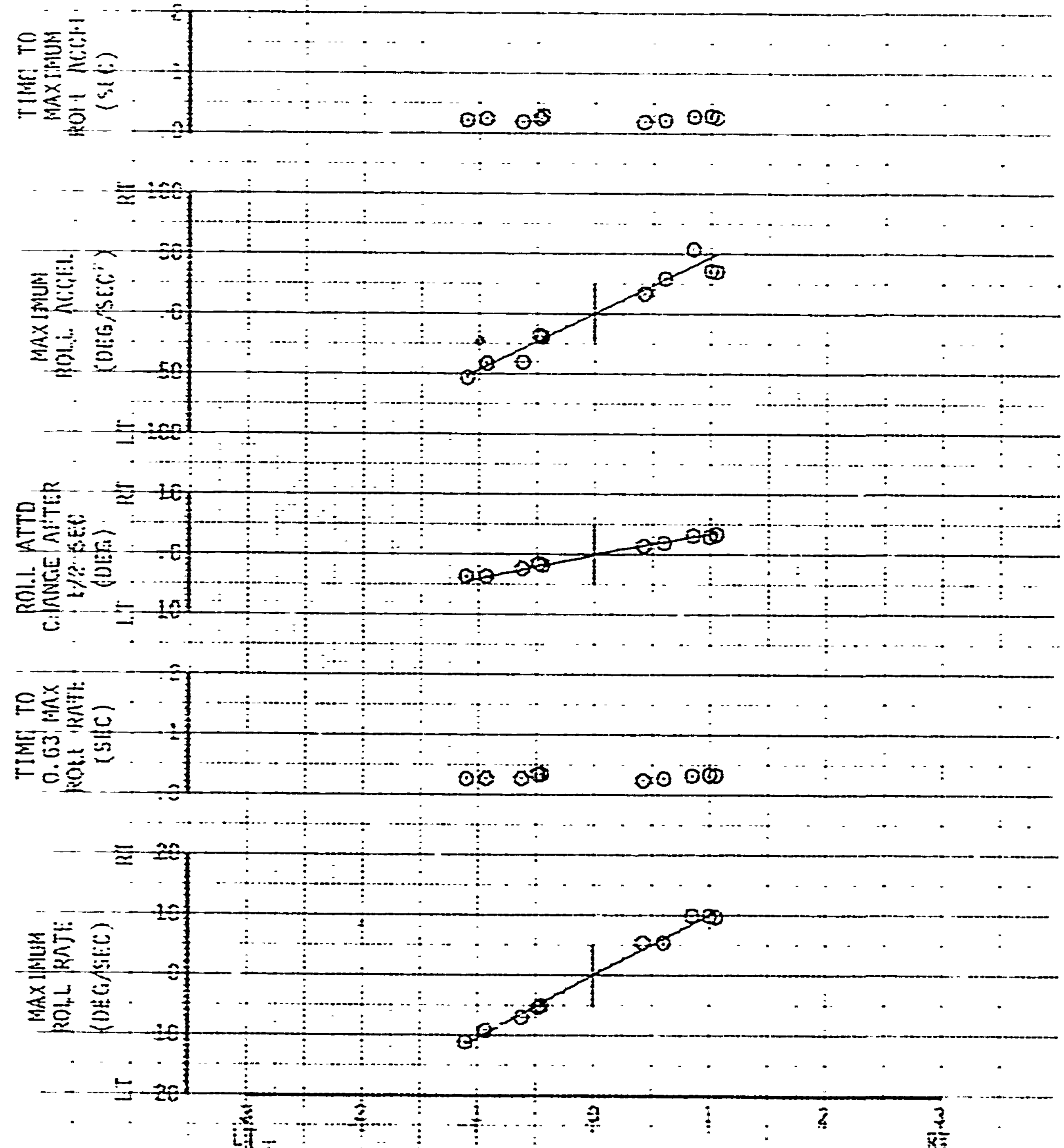


FIGURE 47
LATERAL CONTROLLABILITY
UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	AFCS CONDITION	SYM
16,500	363.9(AFT)	0.0	6100	14.0	258	80	ON	○
16,600	363.8(AFT)	0.0	6300	14.5	258	141	ON	□

NOTE: NORMAL UTILITY CONFIGURATION

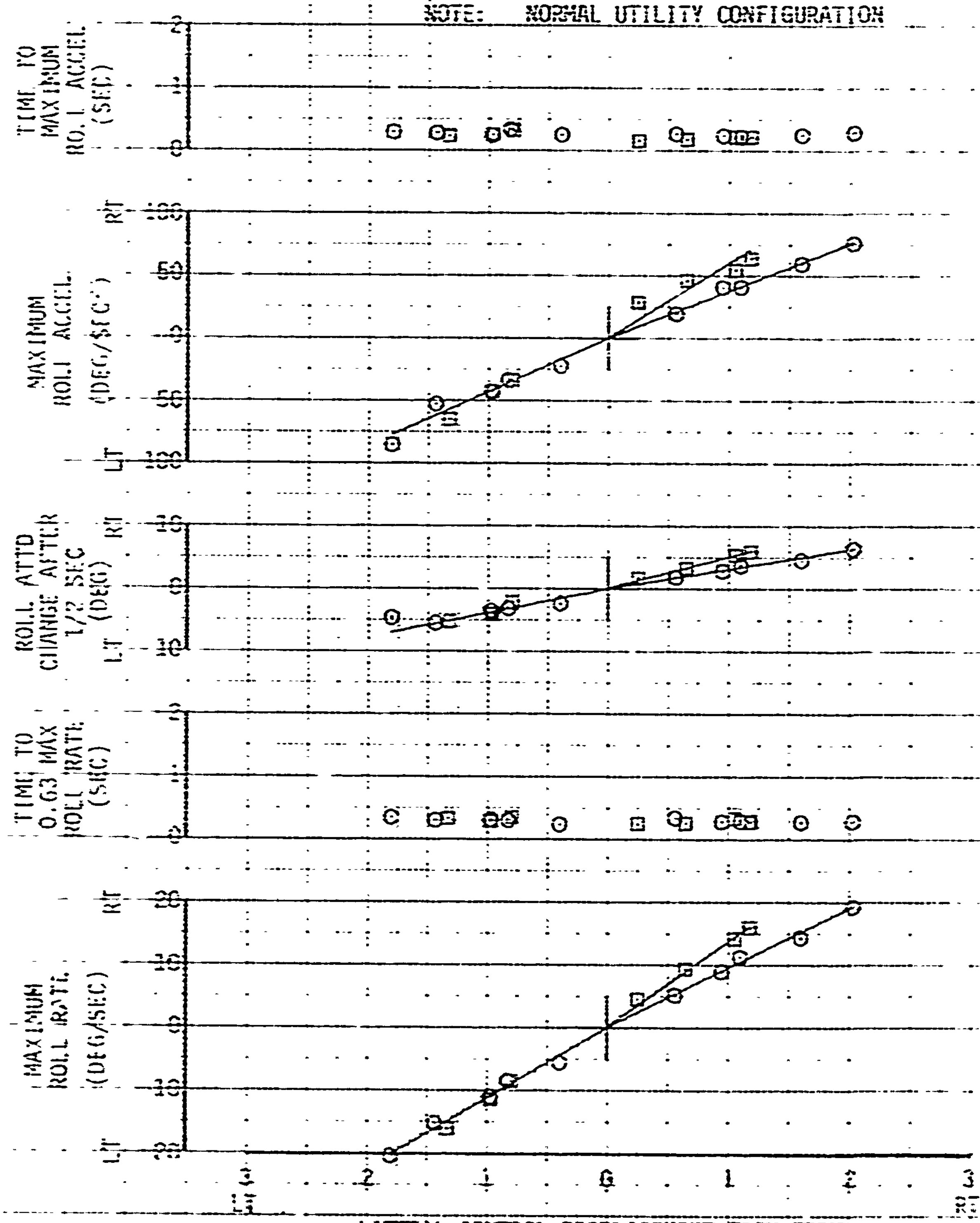


FIGURE 48
LATERAL CONTROLLABILITY
UH-60A USA S/N 77-22718

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	AFCS CONDITION	SYM
21,340	360.3(AFT)	0.0	5900	16.0	259	77	ON	○
21,600	360.3(AFT)	0.0	5900	16.0	258	109	ON	□

NOTE: NORMAL UTILITY CONFIGURATION

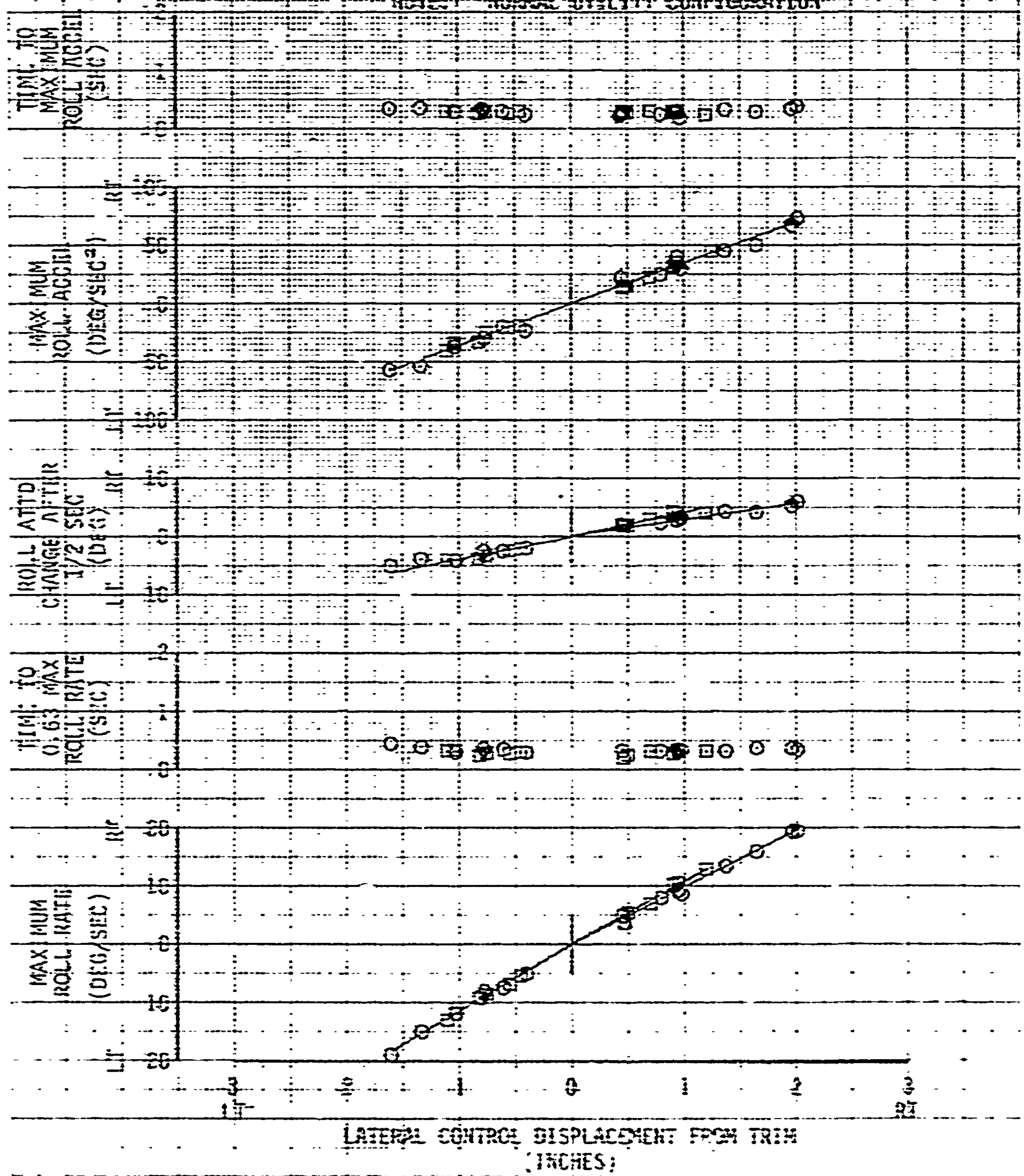


FIGURE 49
LATERAL STEP
UH-60A USA S/N 77-22716

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (DEG C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION	AFCS CONDITION
16020	303.8(AFT)	0.0	8320	14.5	258	140	LEVEL	ON

NOTE: NORMAL UTILITY CONFIGURATION

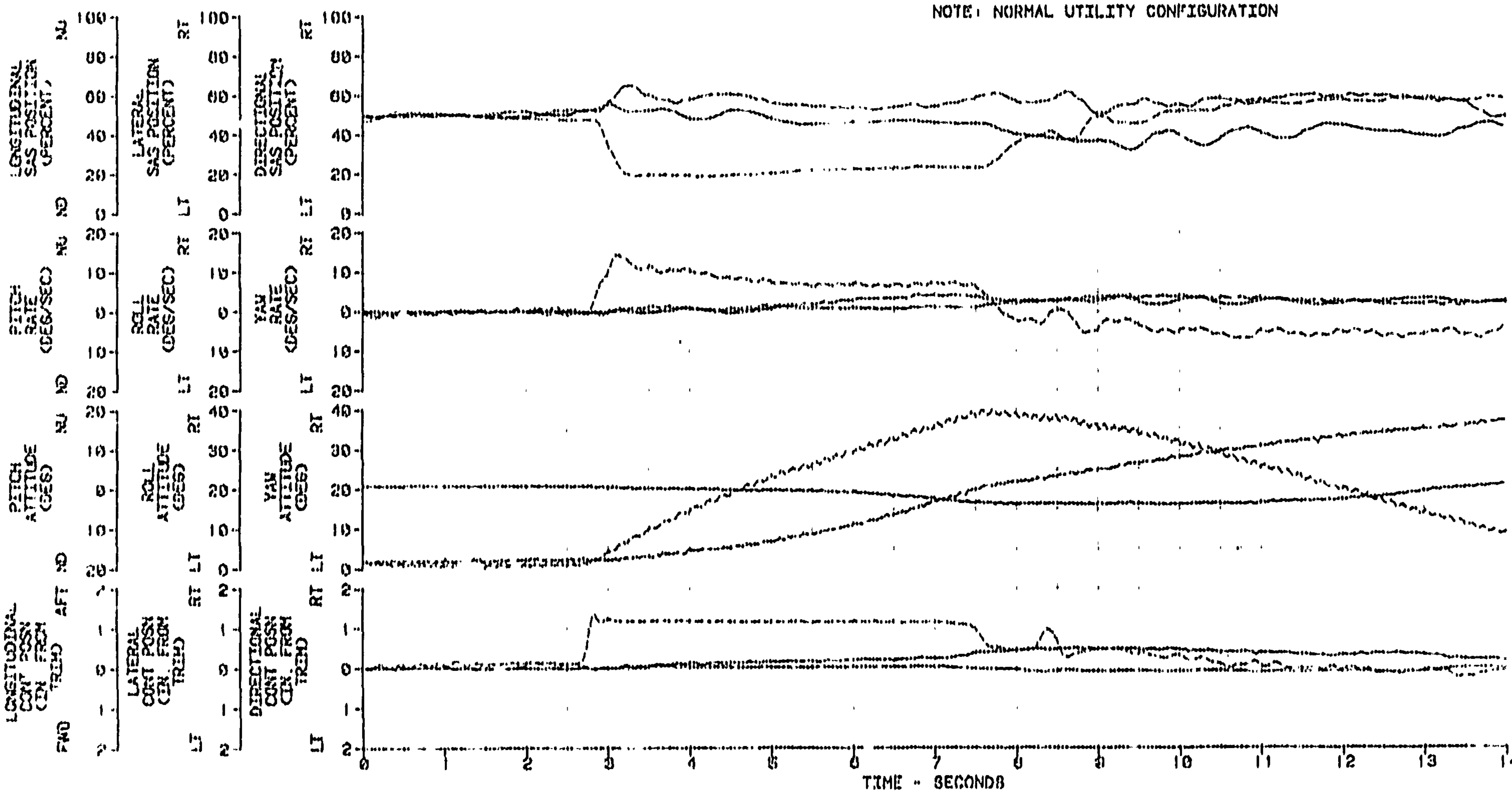


FIGURE 50
LATERAL STEP
UH-60A USA S/N 77-22716

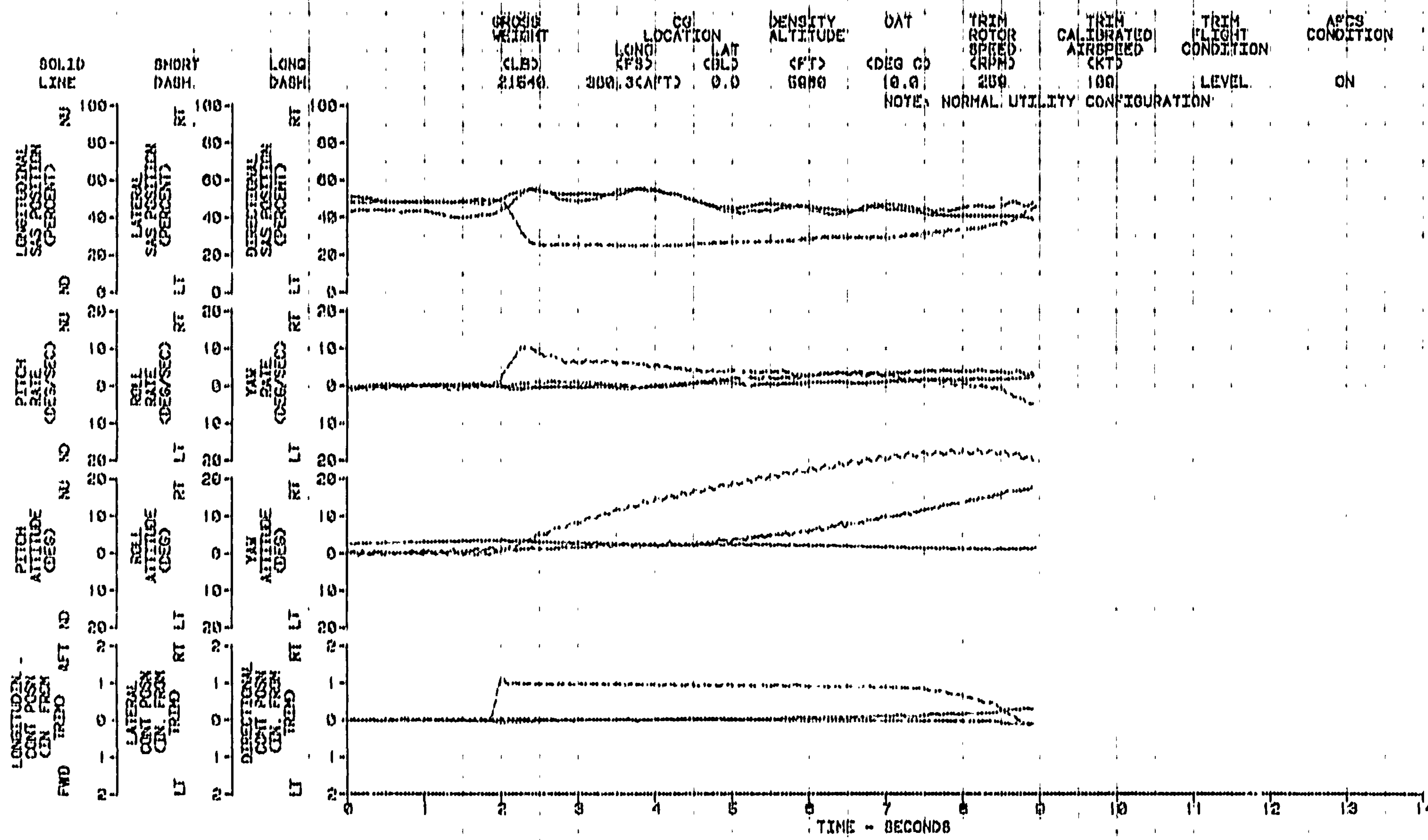


FIGURE 51
DIRECTIONAL CONTROLLABILITY
UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	AFCS CONDITION
16,300	363.6(AFT)	0.0	2180	9.5	258	0	ON

NOTE: NORMAL UTILITY CONFIGURATION

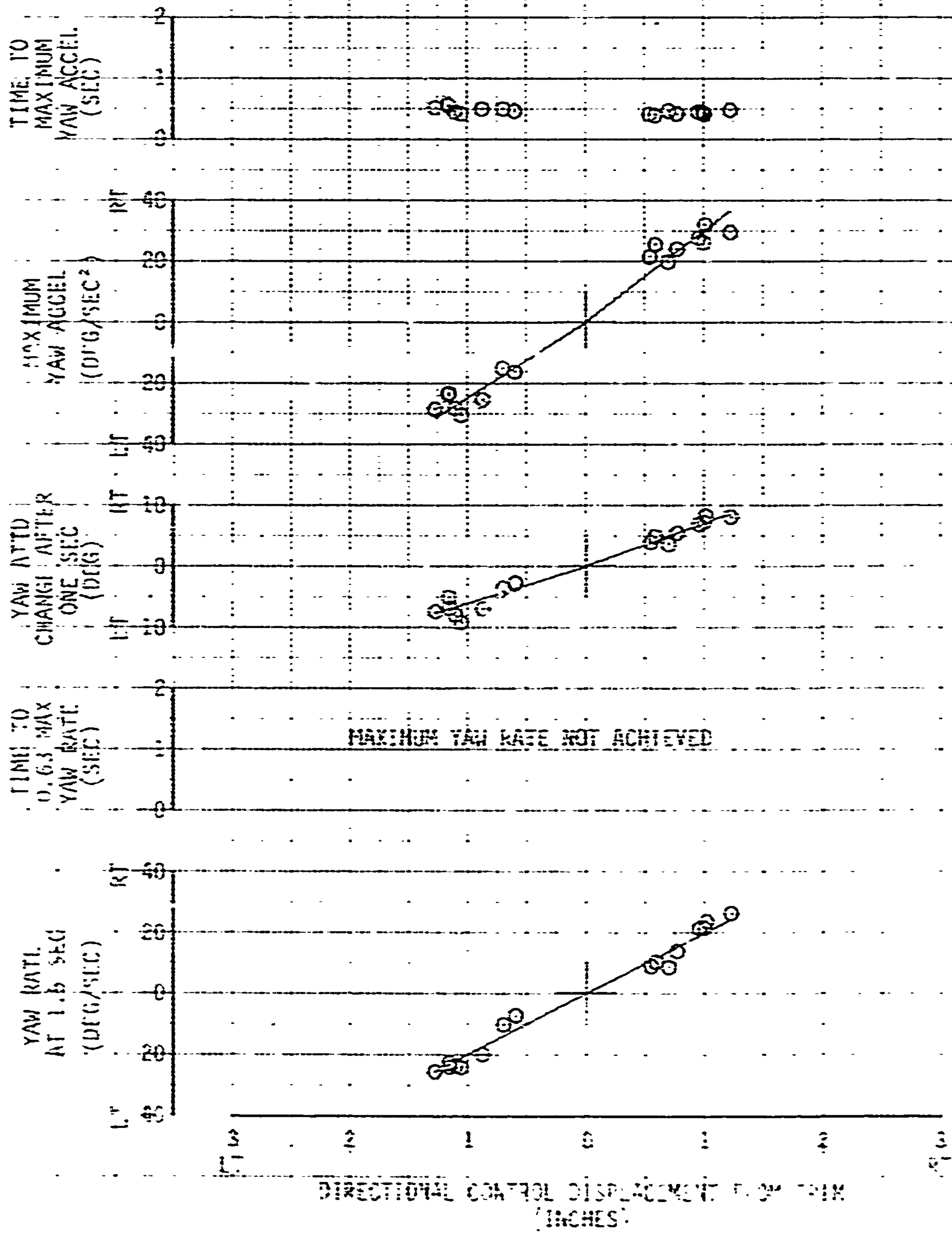


FIGURE 52

DIRECTIONAL CONTROLLABILITY

UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	AFCS CONDITION	SYM
16,200	364.0(AFT)	0.0	6200	14.5	258	79	ON	○
16,300	363.9(AFT)	0.0	6800	15.0	258	142	ON	□

NOTE: NORMAL UTILITY CONFIGURATION

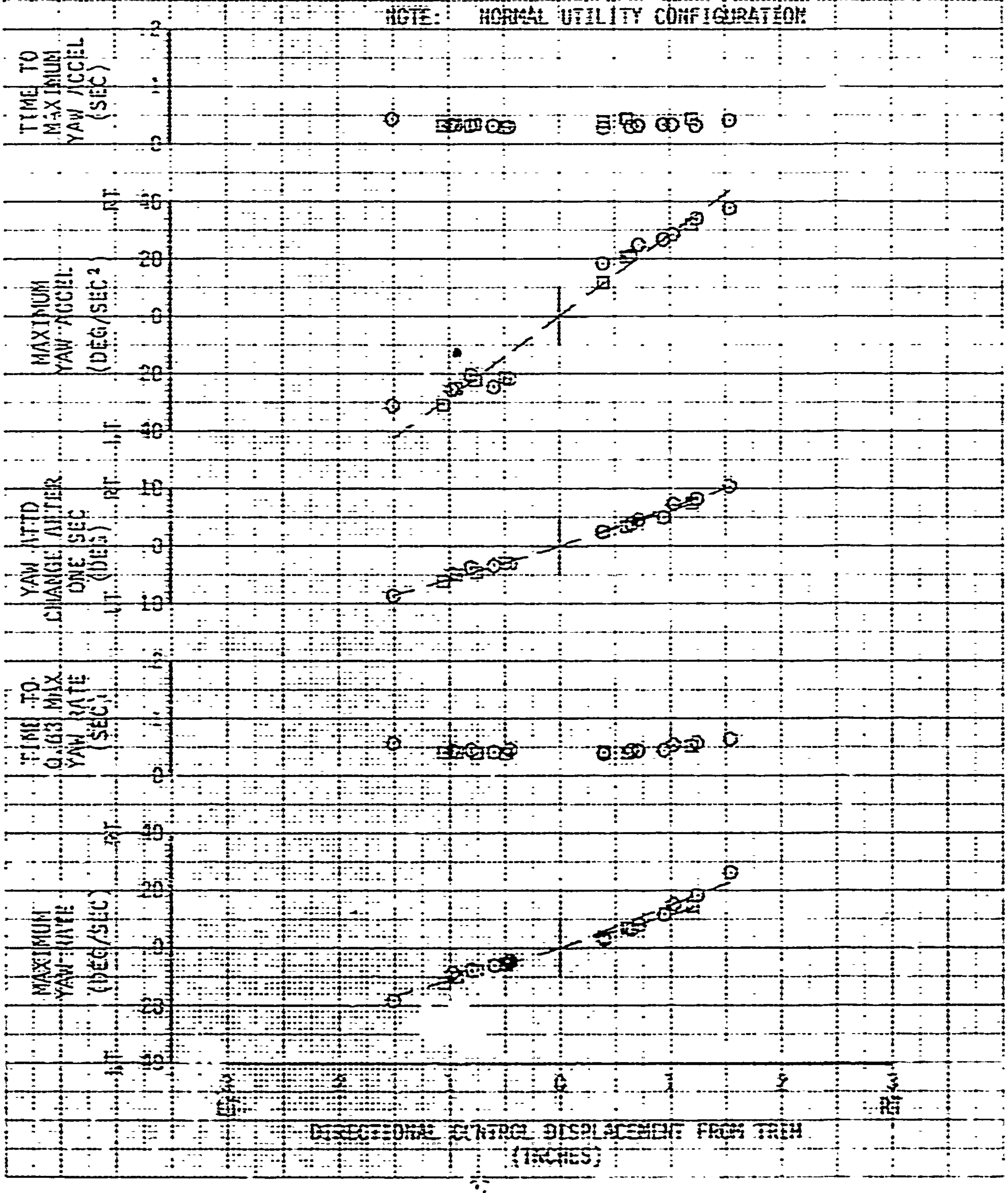


FIGURE 53
DIRECTIONAL CONTROLLABILITY
UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	AFCS CONDITION	SYM
21,000	360.4(AFT)	0.0	5900	16.0	258	77	ON	○
21,260	360.3(AFT)	0.0	6000	9.5	259	110	ON	□

NOTE: NORMAL UTILITY CONFIGURATION

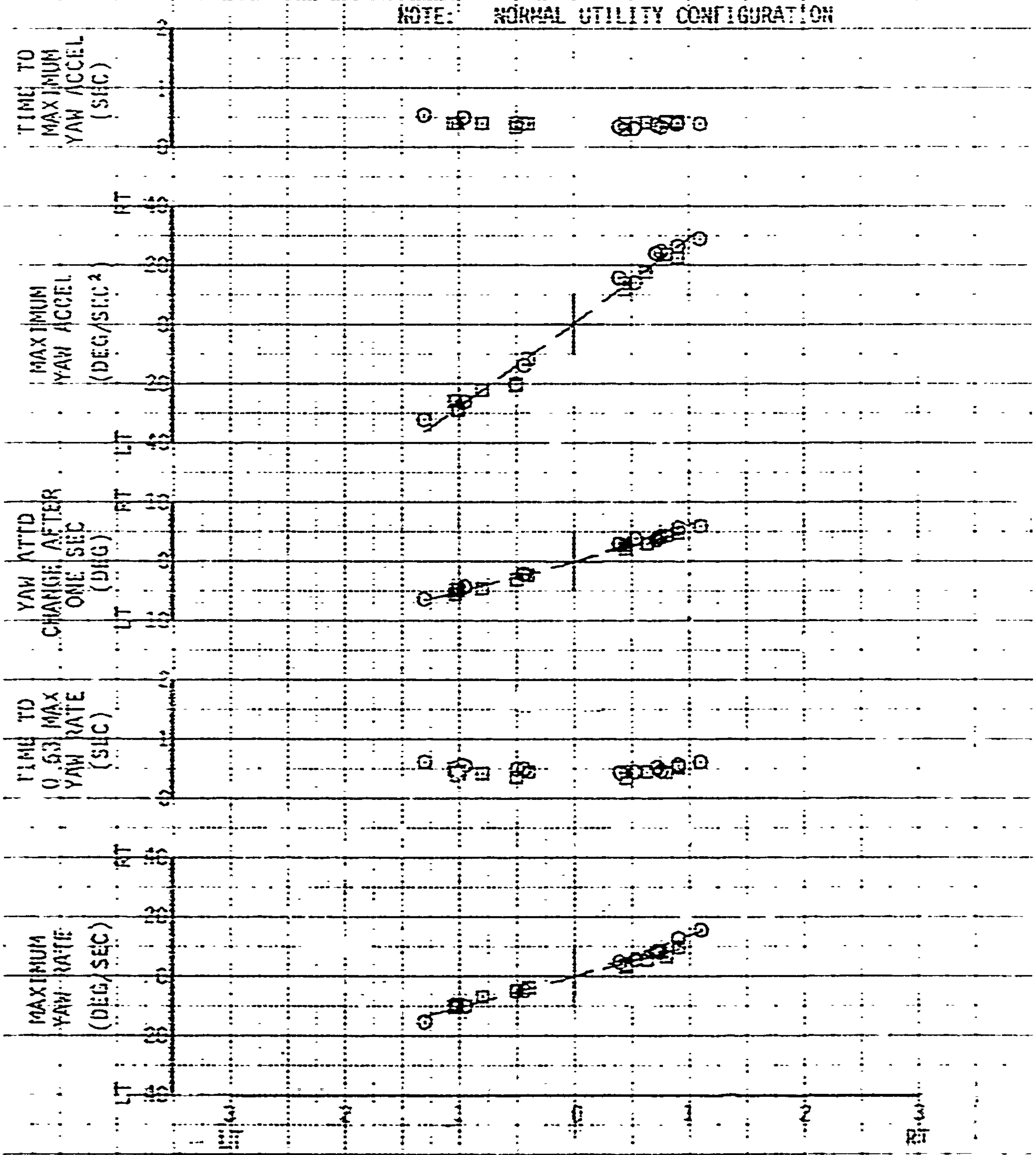


FIGURE 54
DIRECTIONAL STEP
UH-60A USA S/N 77-22710

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (DEG C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION	AFCS CONDITION
16920	303.8(AFT)	0.0	8400	15.5	258	140	LEVEL	ON

NOTE: NORMAL UTILITY CONFIGURATION

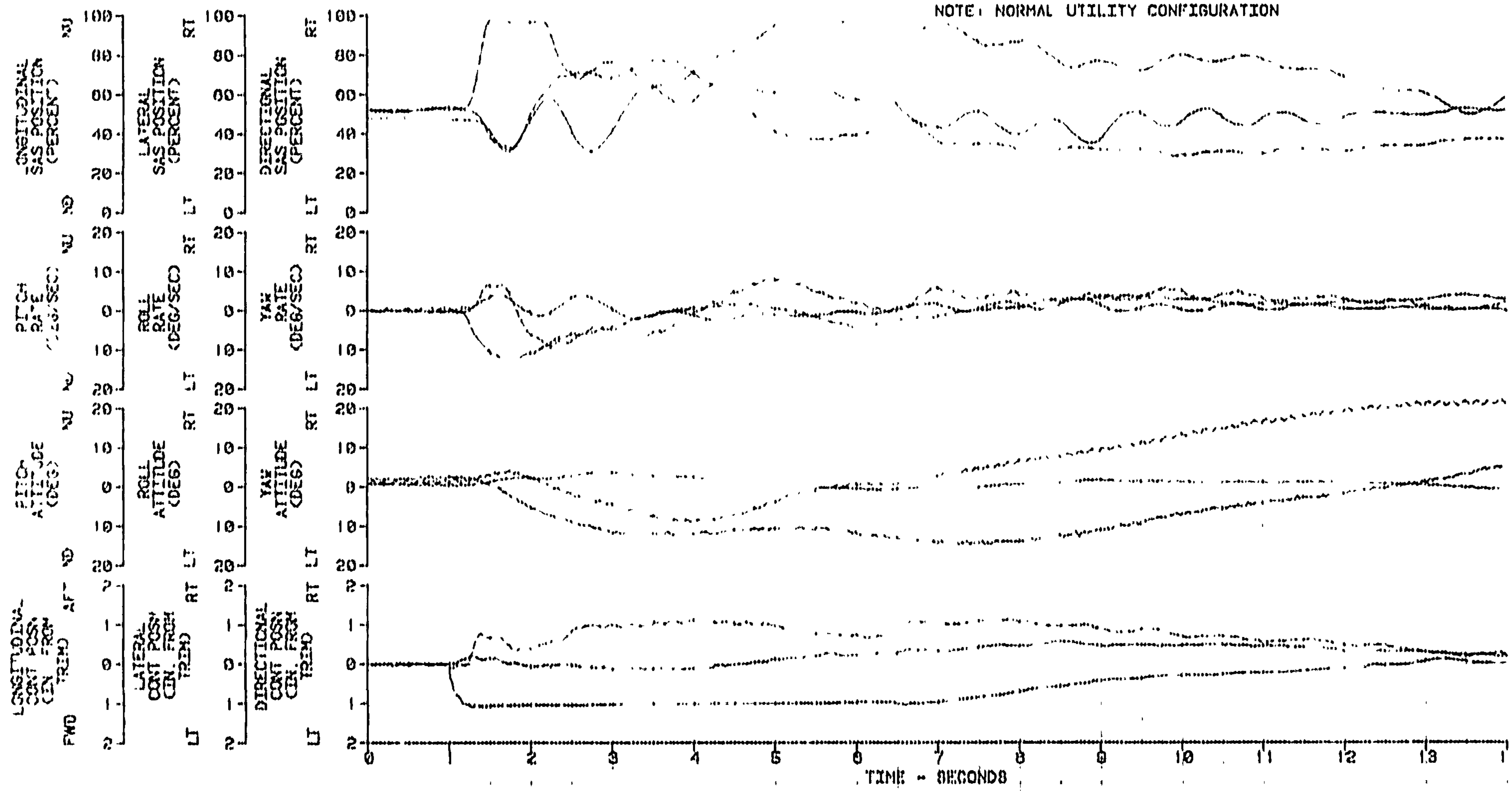


FIGURE 55
DIRECTIONAL STEP
UH-60A USA S/N 77-22718

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (DEG C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION	AFCS CONDITION
21100	360.3(AFT)	0.0	0000	9.0	258	112	LEVEL	ON

NOTE: NORMAL UTILITY CONFIGURATION

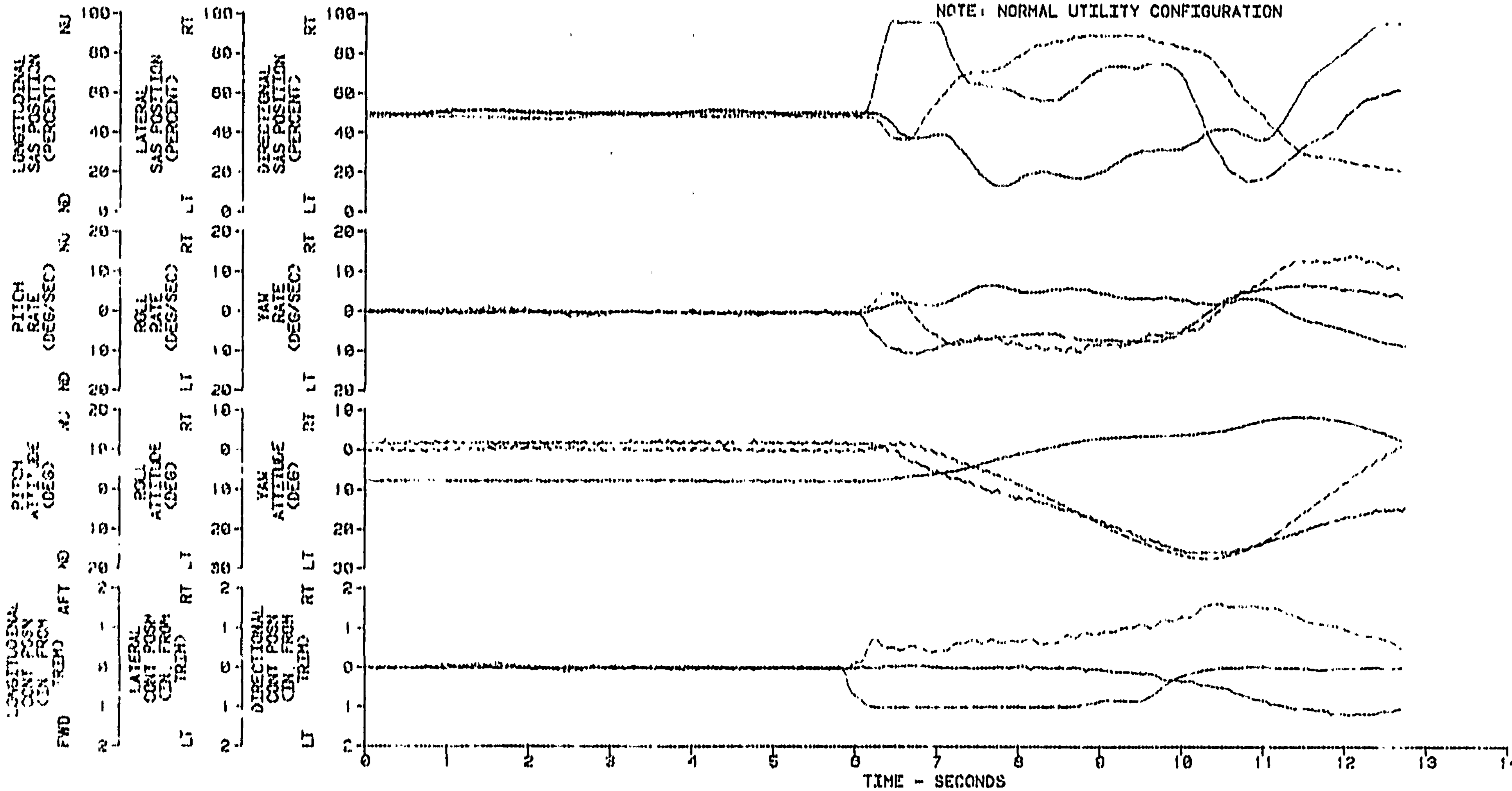


FIGURE 56

SIDEWARD FLIGHT

UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	WHEEL HEIGHT (FT)	AFCS CONDITION
15980	363.6(AFT)	0.0	2060	10.5	258	25	ON

NOTES: 1. I DENOTES CONTROL AND AIRCRAFT EXCURSIONS
2. NORMAL UTILITY CONFIGURATION

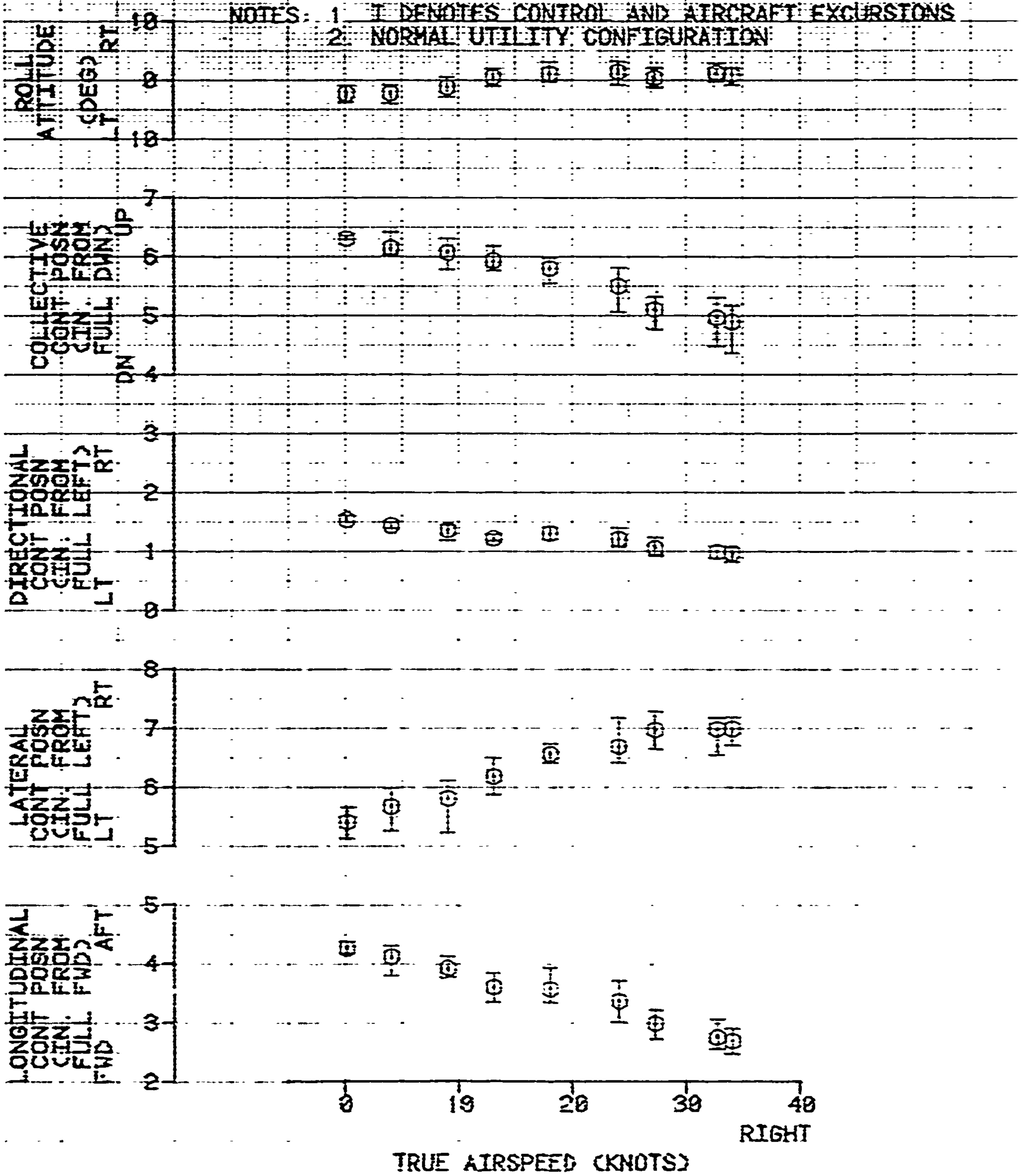


FIGURE 57

REARWARD FLIGHT

UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	WHEEL HEIGHT (FT)	AFCS CONDITION
15820	363.6(AFT)	0.0	2180	11.5	259	25	ON

NOTES: 1. I DENOTES CONTROL AND AIRCRAFT EXCURSIONS
2. NORMAL UTILITY CONFIGURATION

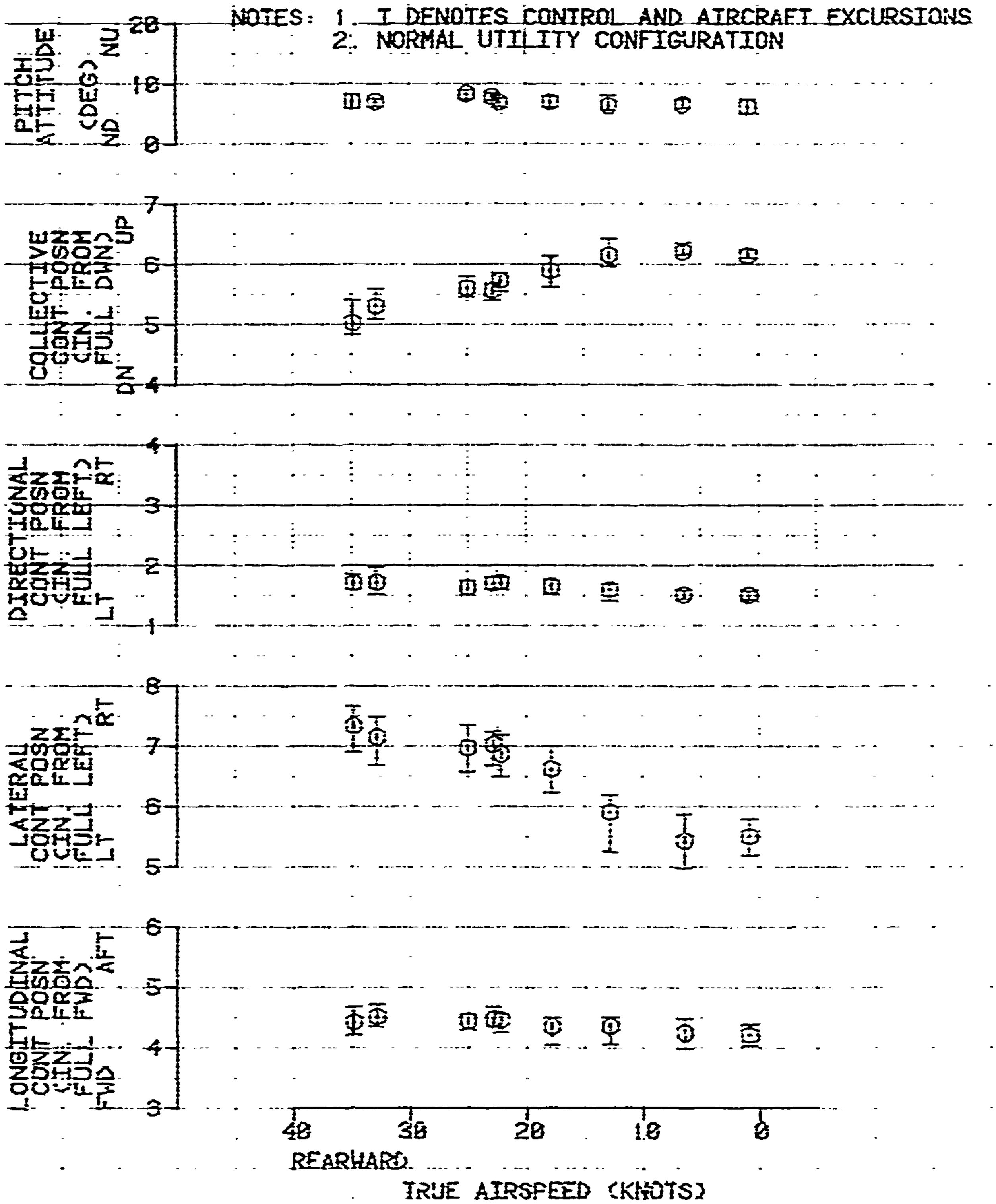


FIGURE 8B

SIMULATED NO. 1 ENGINE FAILURE

UH-60A USA S/N 77-22716

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY CALIBRATED AIRSPEED (KT)	ENTRY ENGINE TORQUE (PERCENT)	ENTRY FLIGHT CONDITION	AFCS CONDITION
16280	355.0(AFT)	0.0	6040	20.5	148	70/71	LEVEL	ON

NOTE: NORMAL UTILITY CONFIGURATION

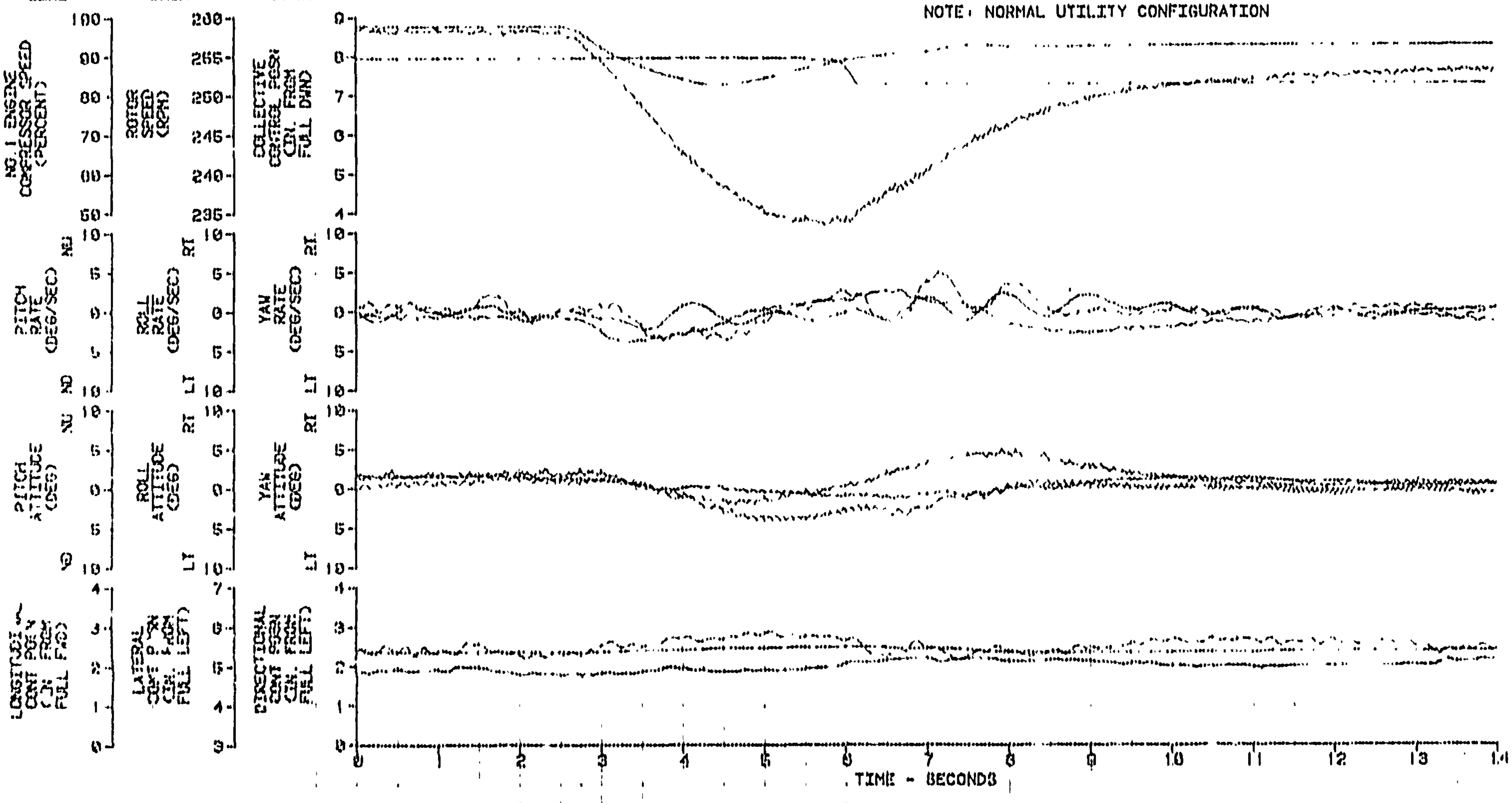


FIGURE 59

SIMULATED NO. 1 ENGINE FAILURE

UH-60A USA S/N 77-22716

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY CALIBRATED AIRSPEED (KT)	ENTRY ENGINE TORQUE (PERCENT)	ENTRY FLIGHT CONDITION	AFCS CONDITION
16300	305.0(AFT)	0.0	0520	20.0	75	33/34	LEVEL	ON

NOTE: NORMAL UTILITY CONFIGURATION

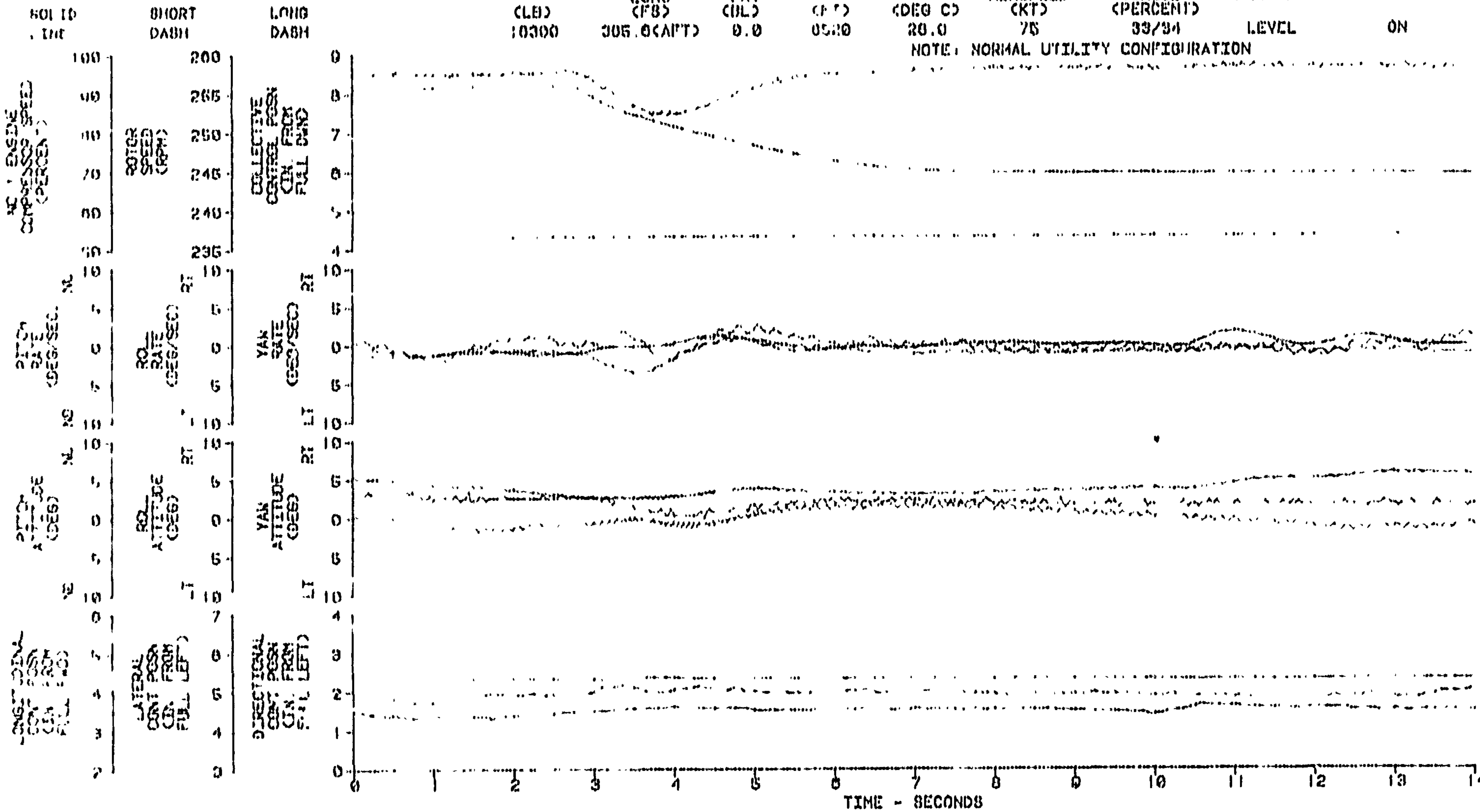


FIGURE 60
SIMULATED STABILATOR HARDOVER
UH-60A USA S/N 77-22716

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY ROTOR SPEED (RPM)	ENTRY CALIBRATED AIRSPEED (KT)	ENTRY FLIGHT CONDITION	AFCS CONDITION
16220	366.2(AFT)	0.0	6000	27.0	258	142	LEVEL	ON

NOTE: NORMAL UTILITY CONFIGURATION

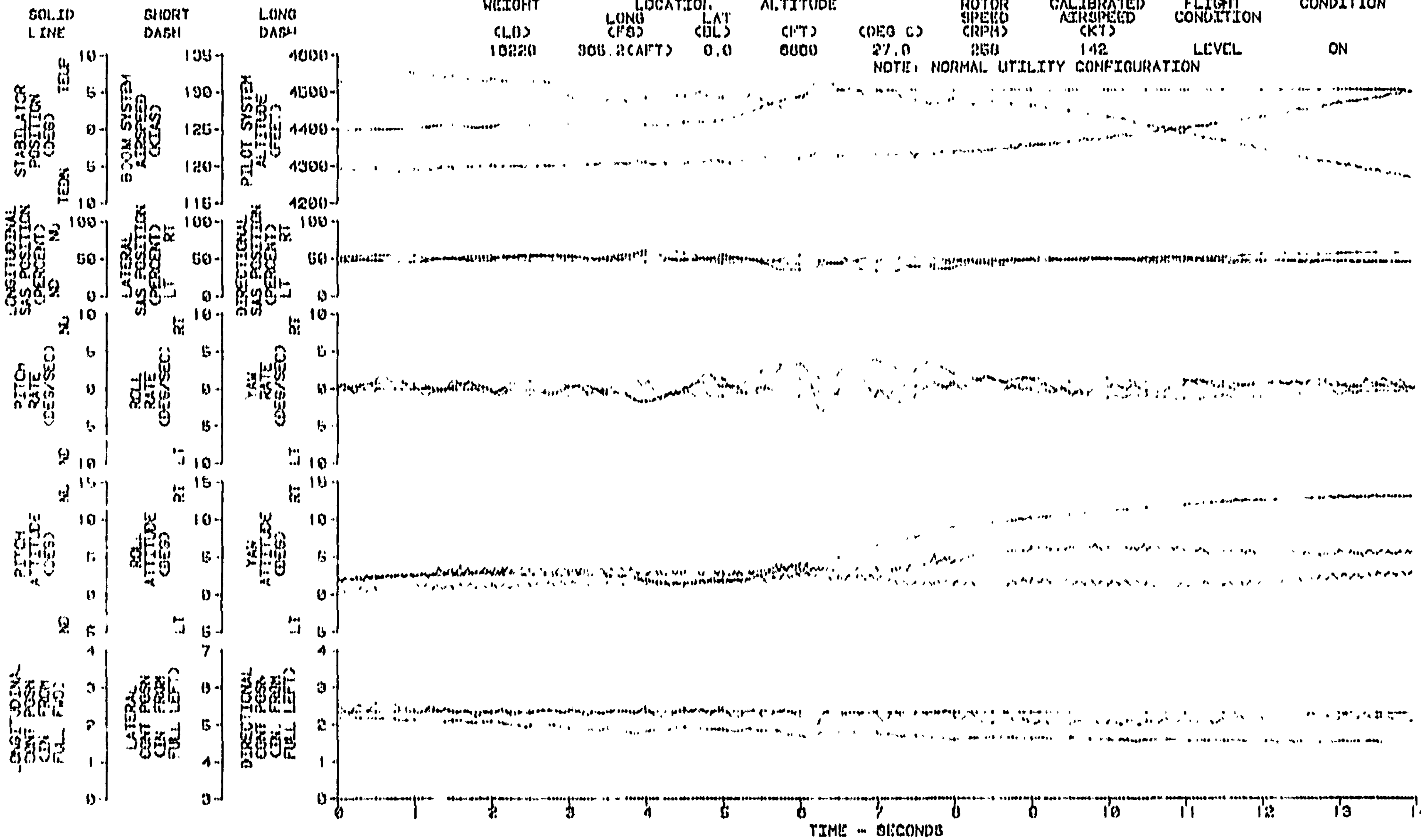


FIGURE 61

PILOT SEAT VIBRATION CHARACTERISTICS

UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
16200	347.1(FWD)	0.0	13860	7.0	254	LEVEL	ON

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. ⊡ = 1/REV; ⊙ = 4/REV; △ = 8/REV

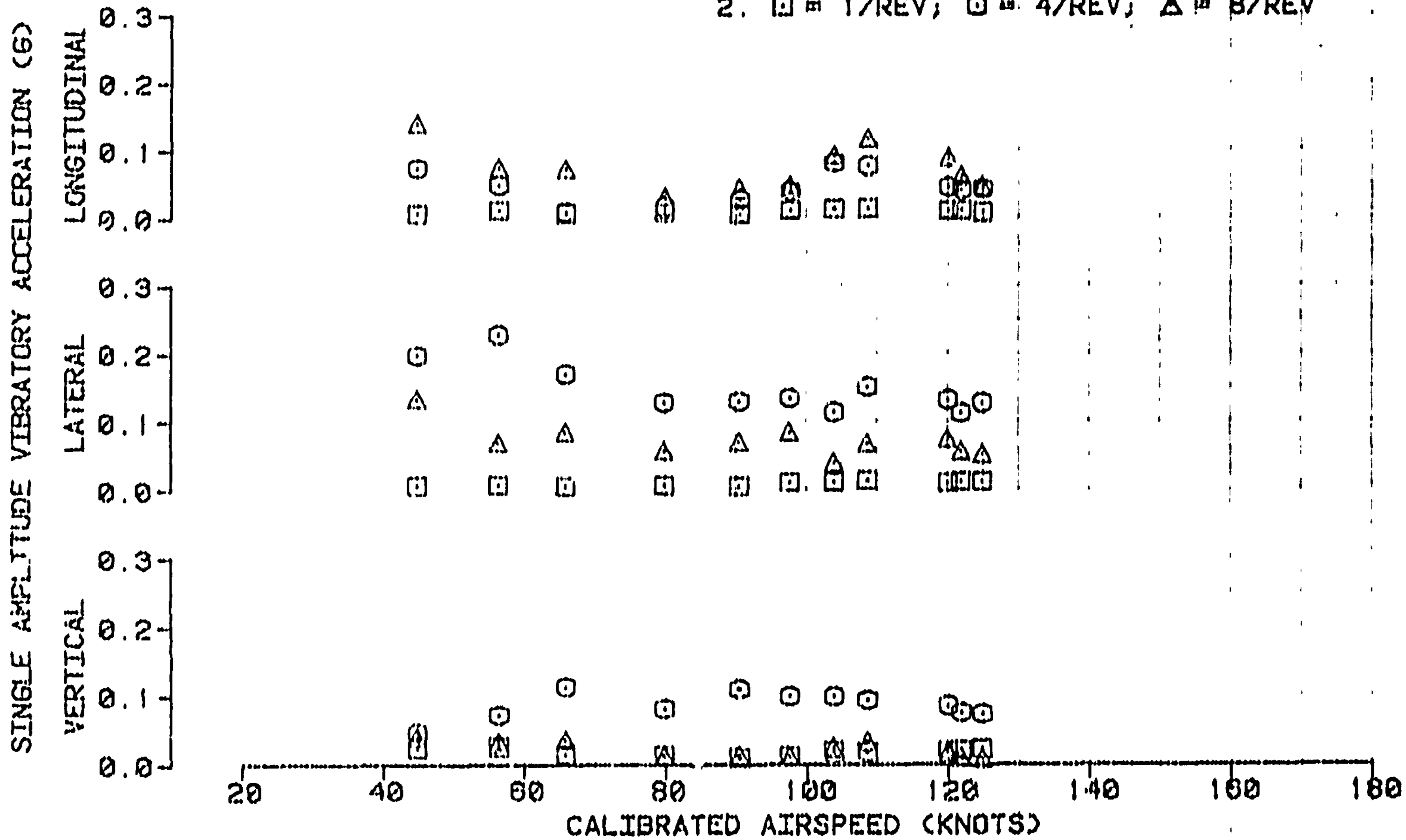


FIGURE 62

PILOT SEAT VIBRATION CHARACTERISTICS

UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
16580	305.4(AFT)	0.0	13220	8.5	256	LEVEL	ON

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. ⊡ = 1/REV, ⊙ = 4/REV, △ = 8/REV

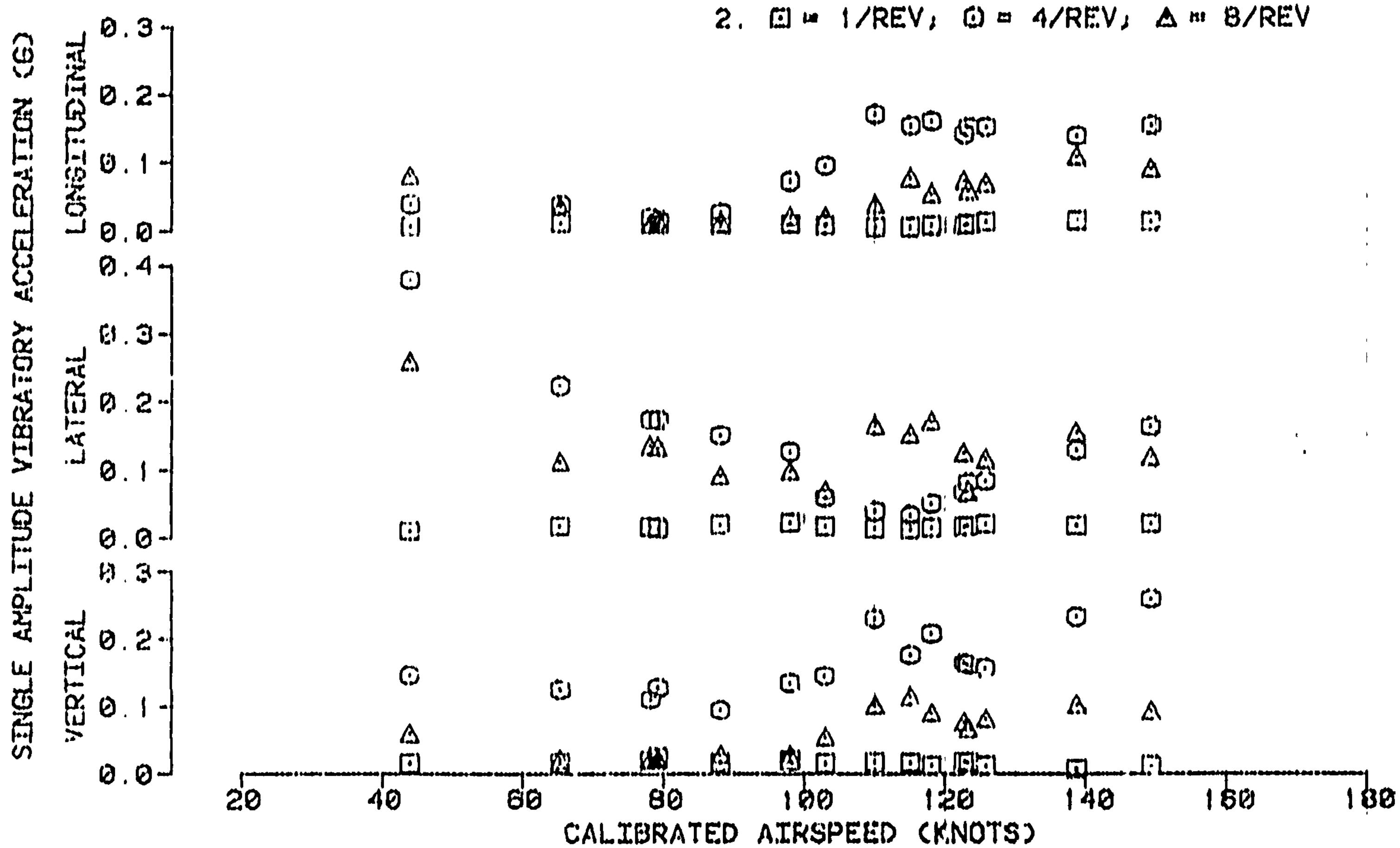


FIGURE 63

PILOT SEAT VIBRATION CHARACTERISTICS

UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
21380	347.1(FWD)	0.0	6620	22.0	261	LEVEL	ON

NOTES: 1. NORMAL UTILITY CONFIGURATION

2. ⊡ = 1/REV, ⊙ = 4/REV, △ = 8/REV

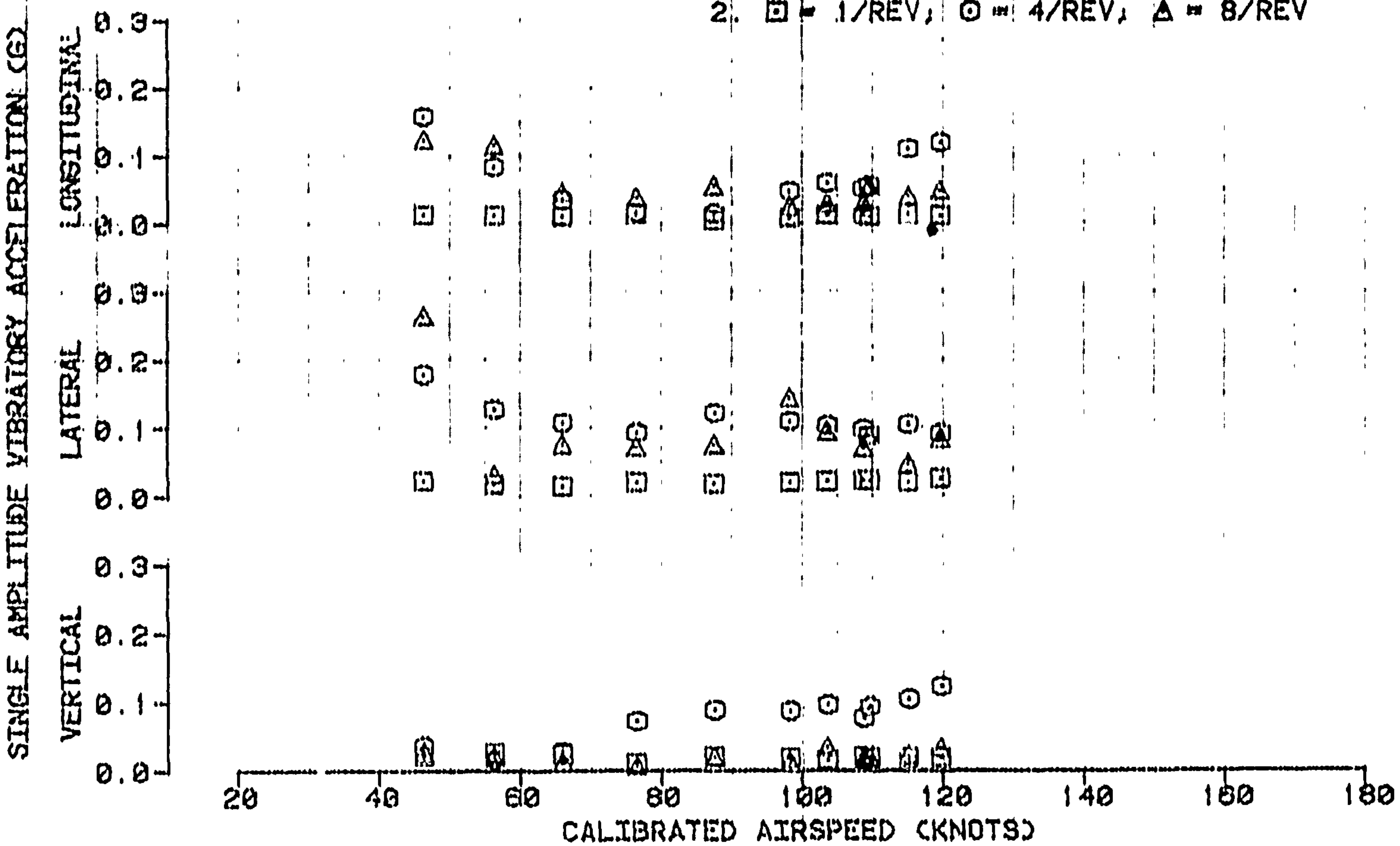


FIGURE 64

PILOT SEAT VIBRATION CHARACTERISTICS

UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
21330	360.2(AFT)	0.0	9380	17.5	259	LEVEL	ON

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. ⊡ = 1/REV; ⊙ = 4/REV; △ = 8/REV

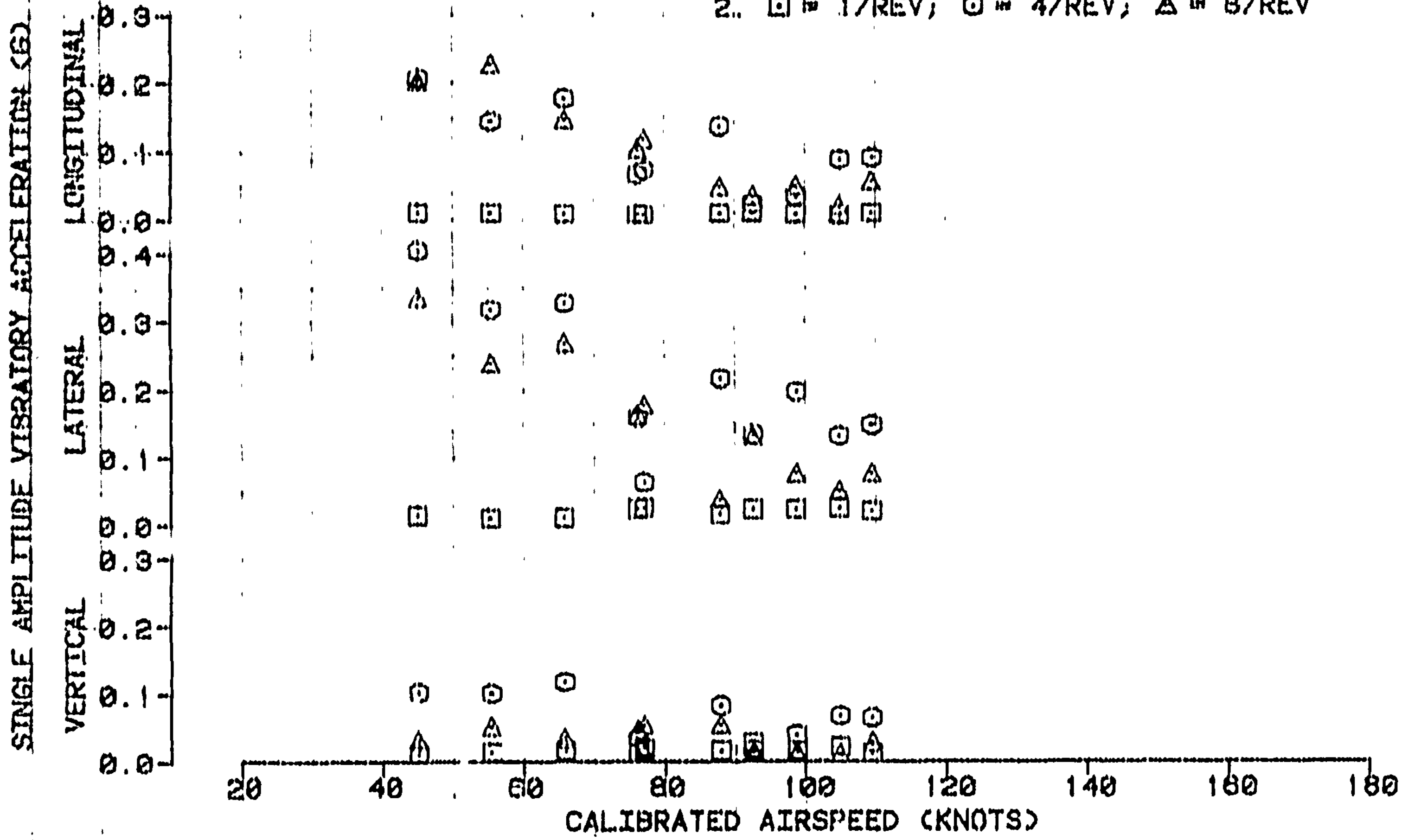


FIGURE 65

PILOT FLOOR VIBRATION CHARACTERISTICS

UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
16200	347.1(FWD)	0.0	13880	7.0	254	LEVEL	ON

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. ⊡ = 1/REV; ⊙ = 4/REV; △ = 8/REV

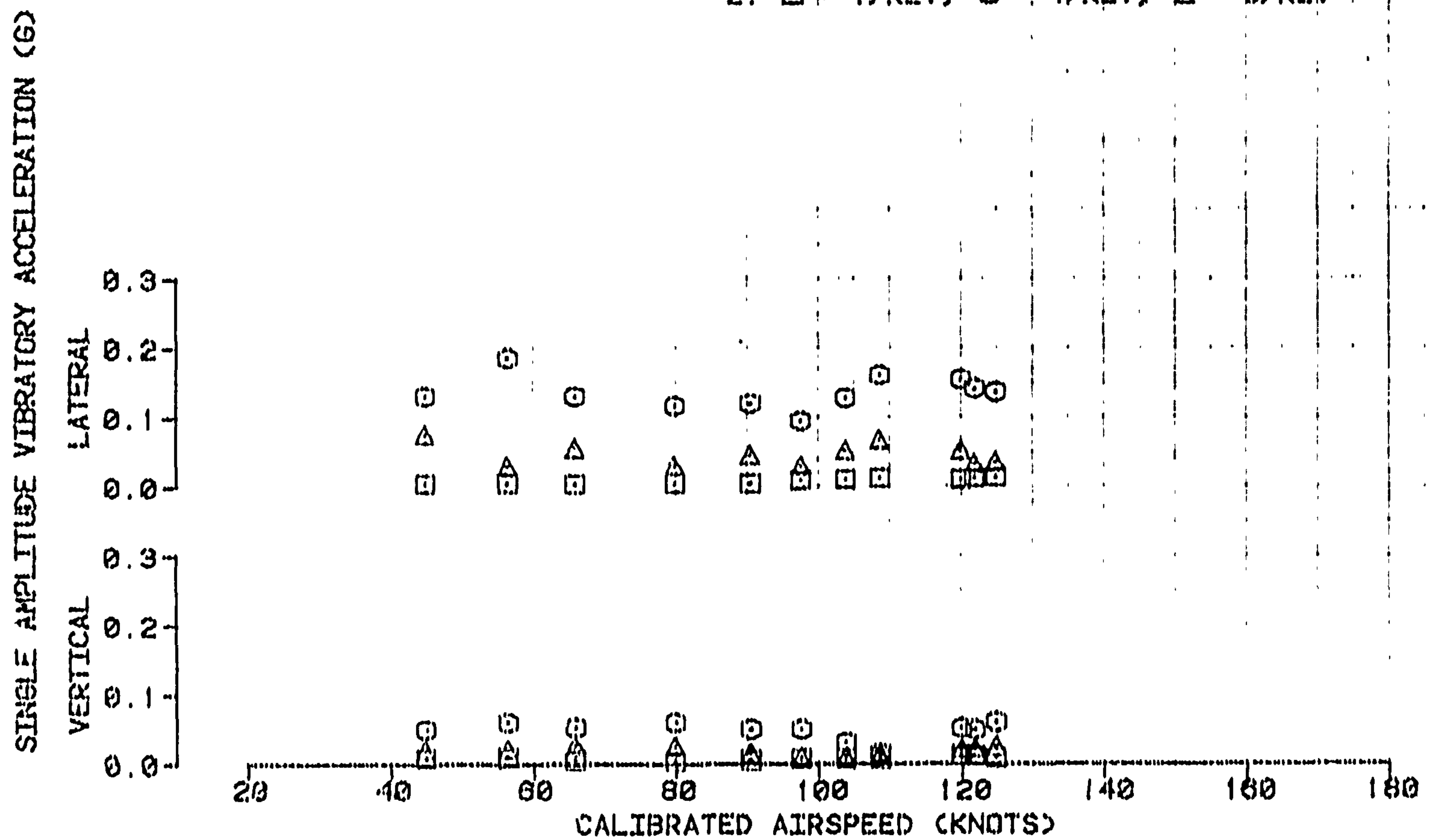


FIGURE 66

PILOT FLOOR VIBRATION CHARACTERISTICS

UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
16560	365.4(AFT)	0.0	13220	8.5	255.	LEVEL	ON

NOTES: 1. NORMAL UTILITY CONFIGURATION

2. ⊡ = 1/REV; ⊙ = 4/REV; △ = 8/REV

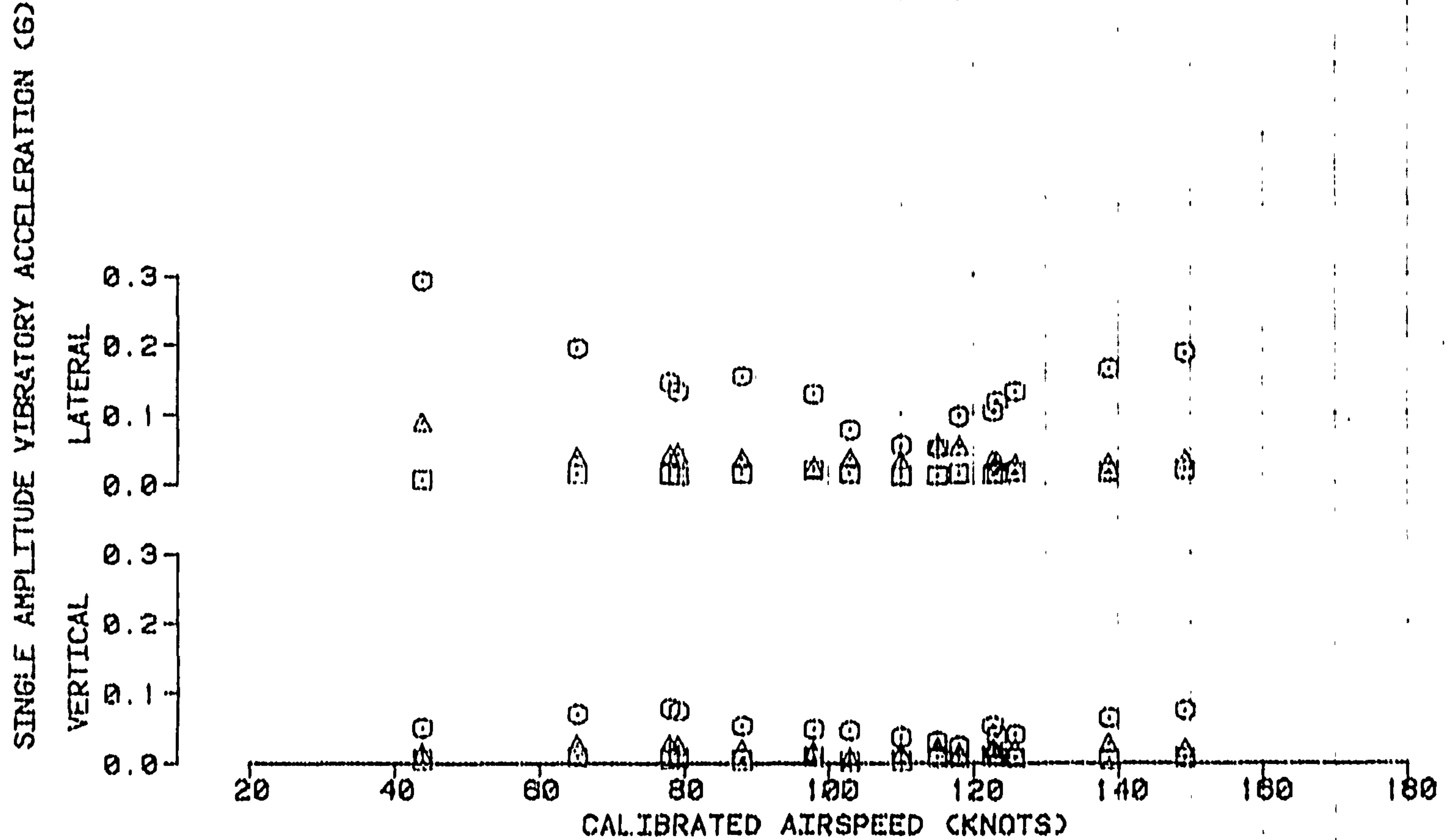


FIGURE 67.

PILOT FLOOR VIBRATION CHARACTERISTICS

UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
21380.	347.1(FWD)	0.0	8620	22.0	261	LEVEL	ON

NOTES: 1. NORMAL UTILITY CONFIGURATION

2. ⊡ = 1/REV; ⊙ = 4/REV; △ = 8/REV

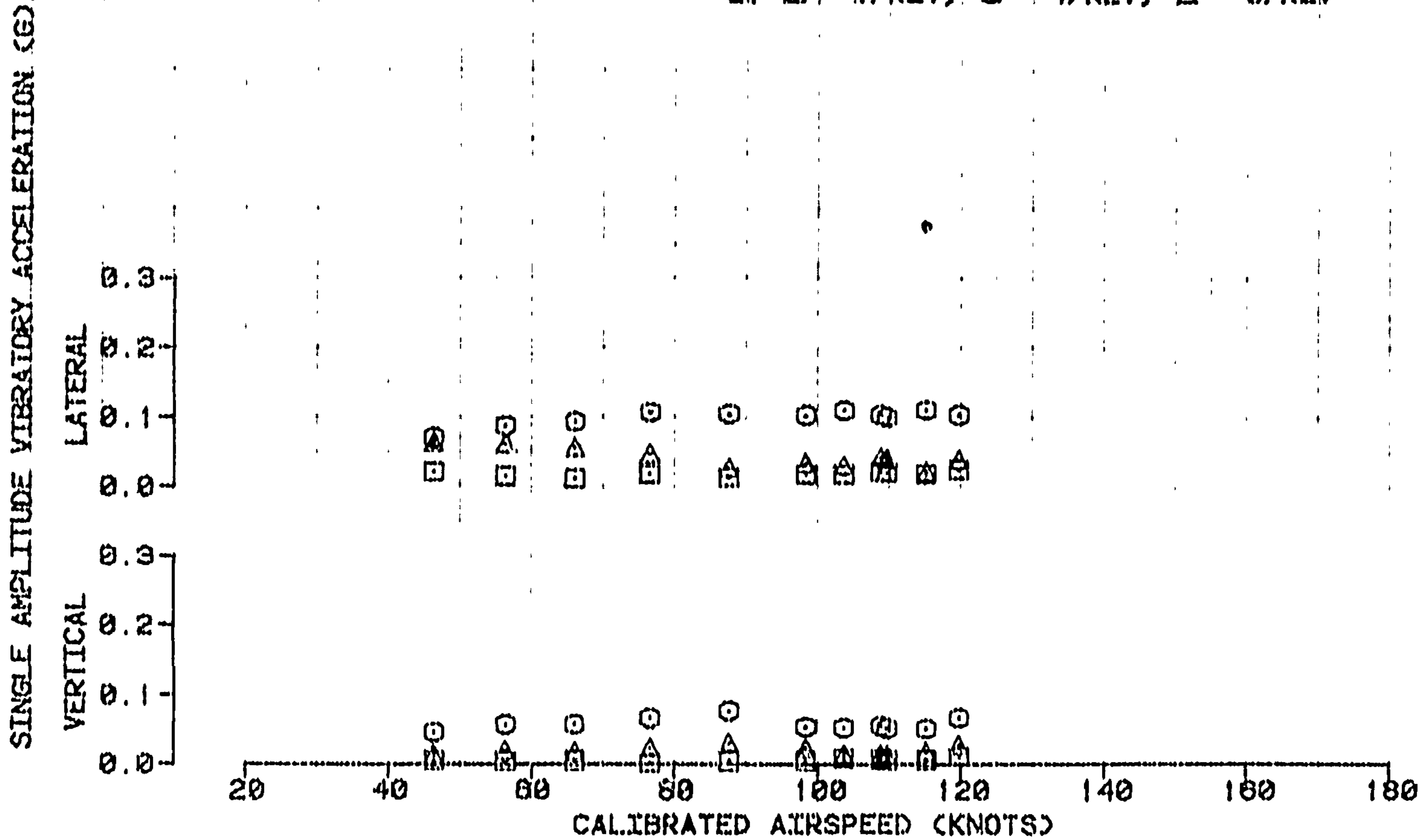


FIGURE 68

PILOT FLOOR VIBRATION CHARACTERISTICS

UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG. ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
21330	360.2(AFT)	0.0	9380	17.5	258	LEVEL	ON

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. ⊡ = 1/REV, ⊙ = 4/REV, ⚠ = 8/REV

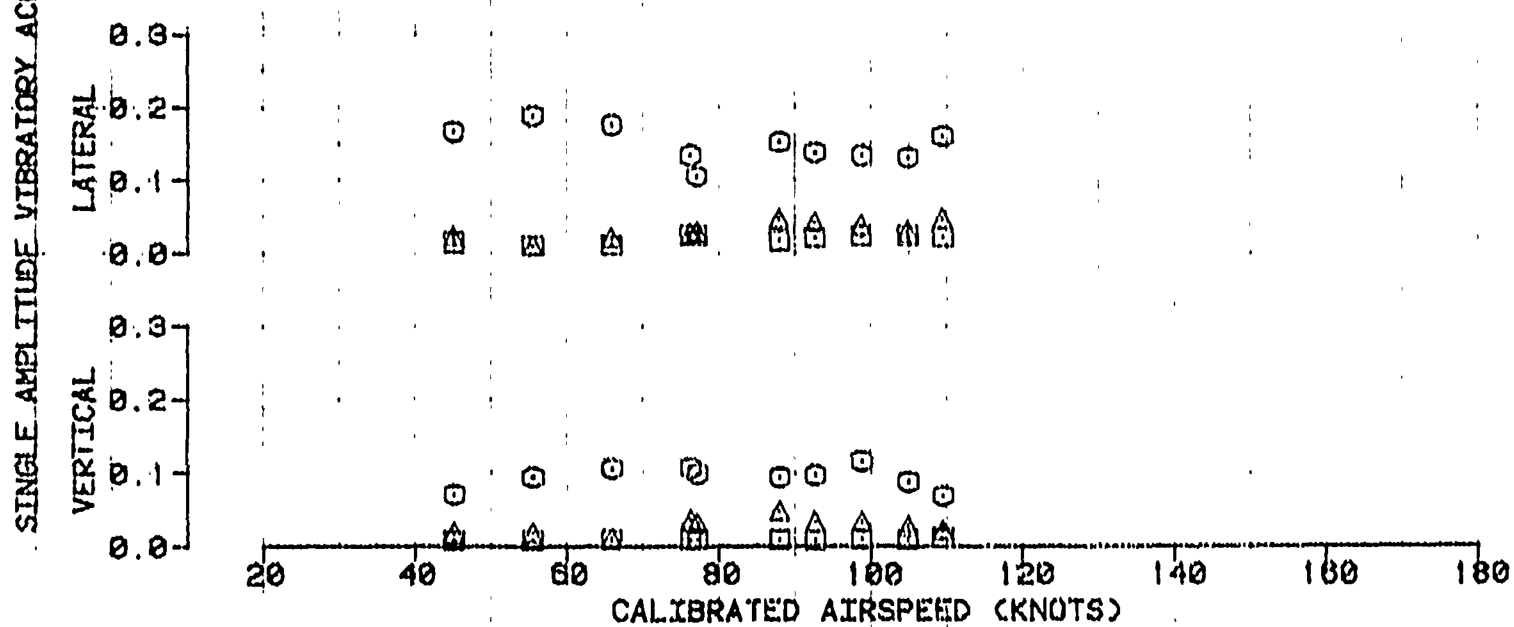


FIGURE 69

CENTER OF GRAVITY VIBRATION CHARACTERISTICS

UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
16200	347.1(FWD)	0.0	13860	7.0	254	LEVEL	ON

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. ⊡ = 1/REV; ⊙ = 4/REV; △ = 8/REV

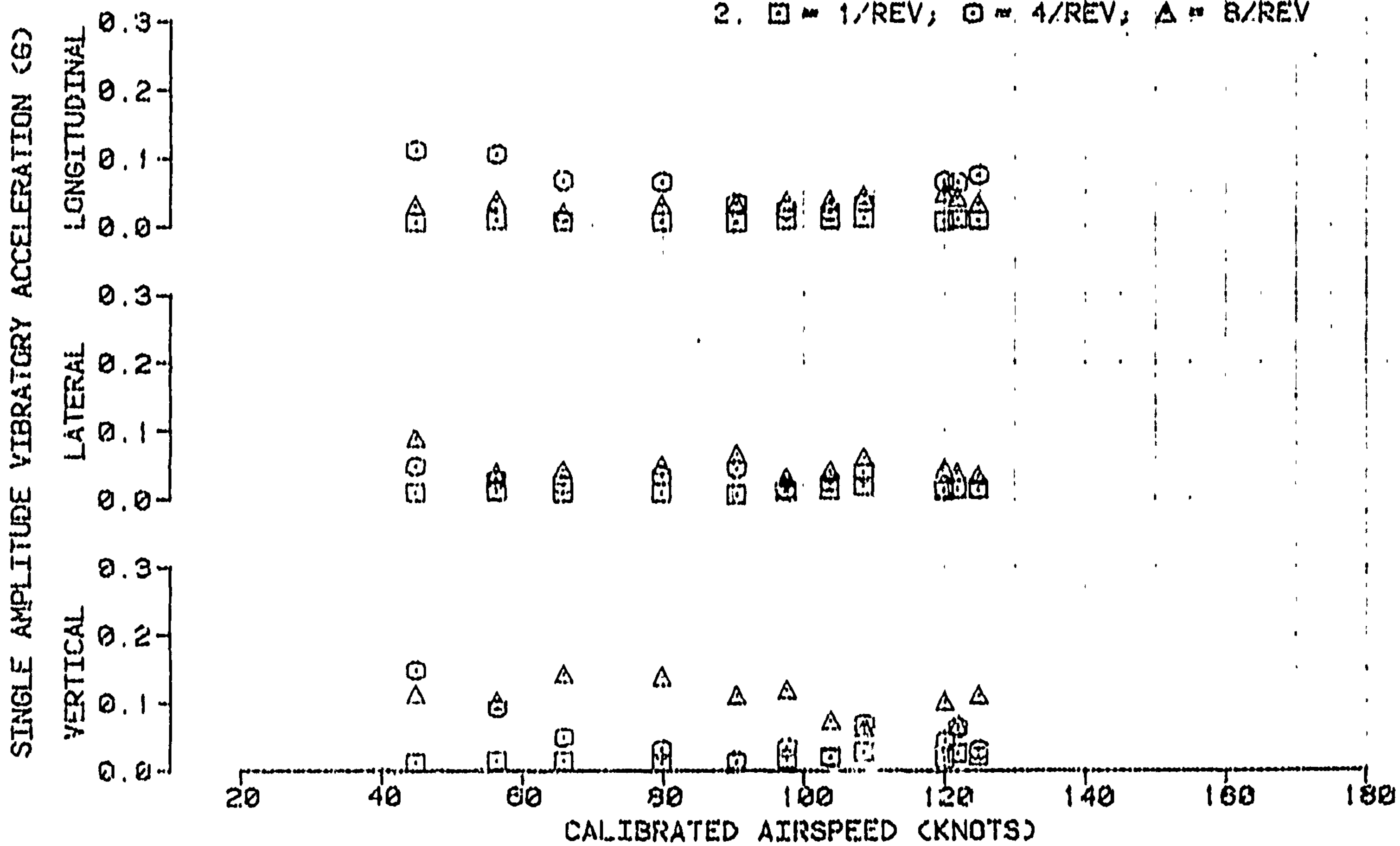


FIGURE 70.
CENTER OF GRAVITY VIBRATION CHARACTERISTICS
UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
16580	365.4(AFT)	0.0	13220	8.5	255	LEVEL	ON

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. ⊡ = 1/REV; ⊙ = 4/REV; △ = 8/REV

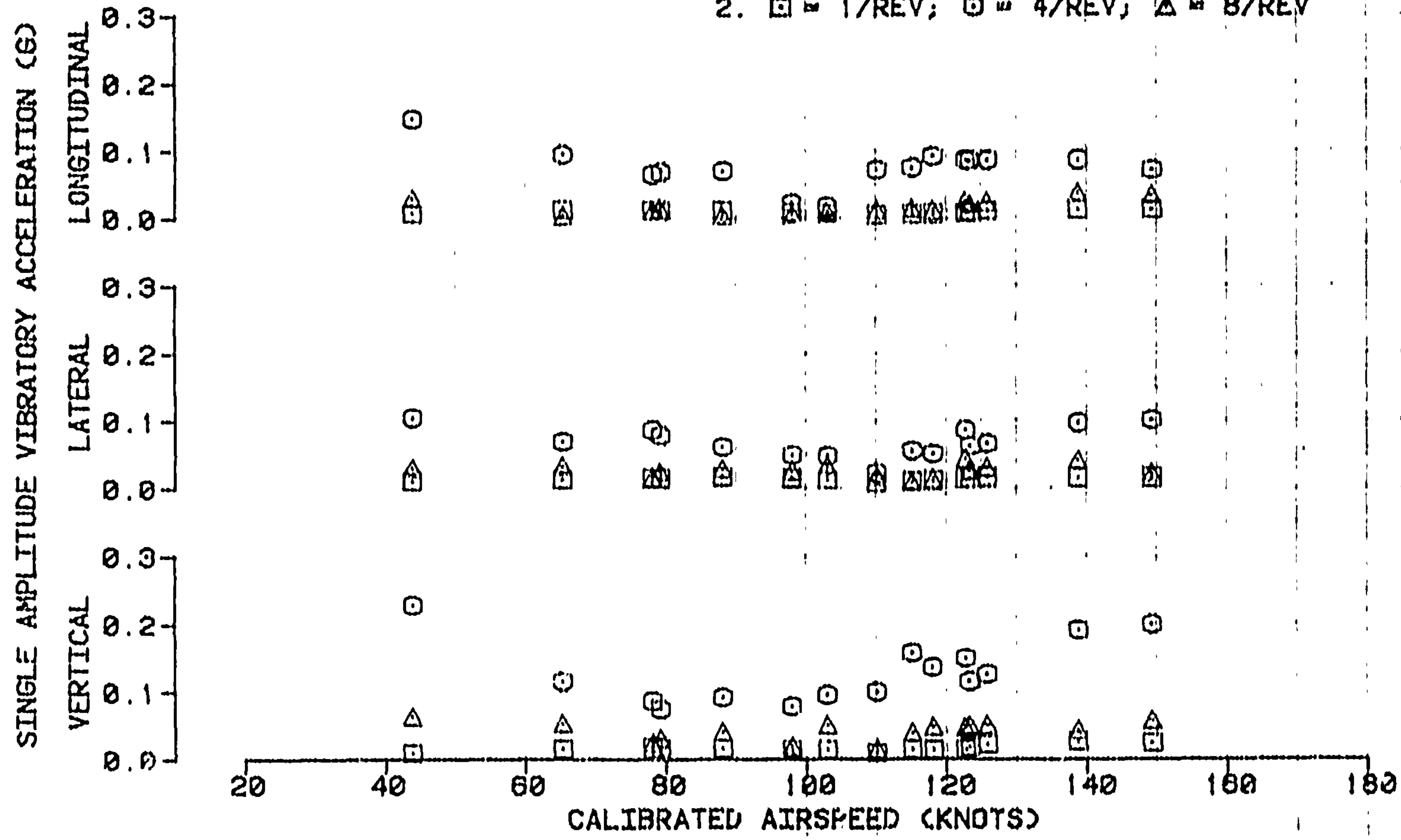


FIGURE 71

CENTER OF GRAVITY VIBRATION CHARACTERISTICS

UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
21380	347.1(FWD)	0.0	6620	22.0	261	LEVEL	ON

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. ⊡ = 1/REV; ⊙ = 4/REV; △ = 8/REV

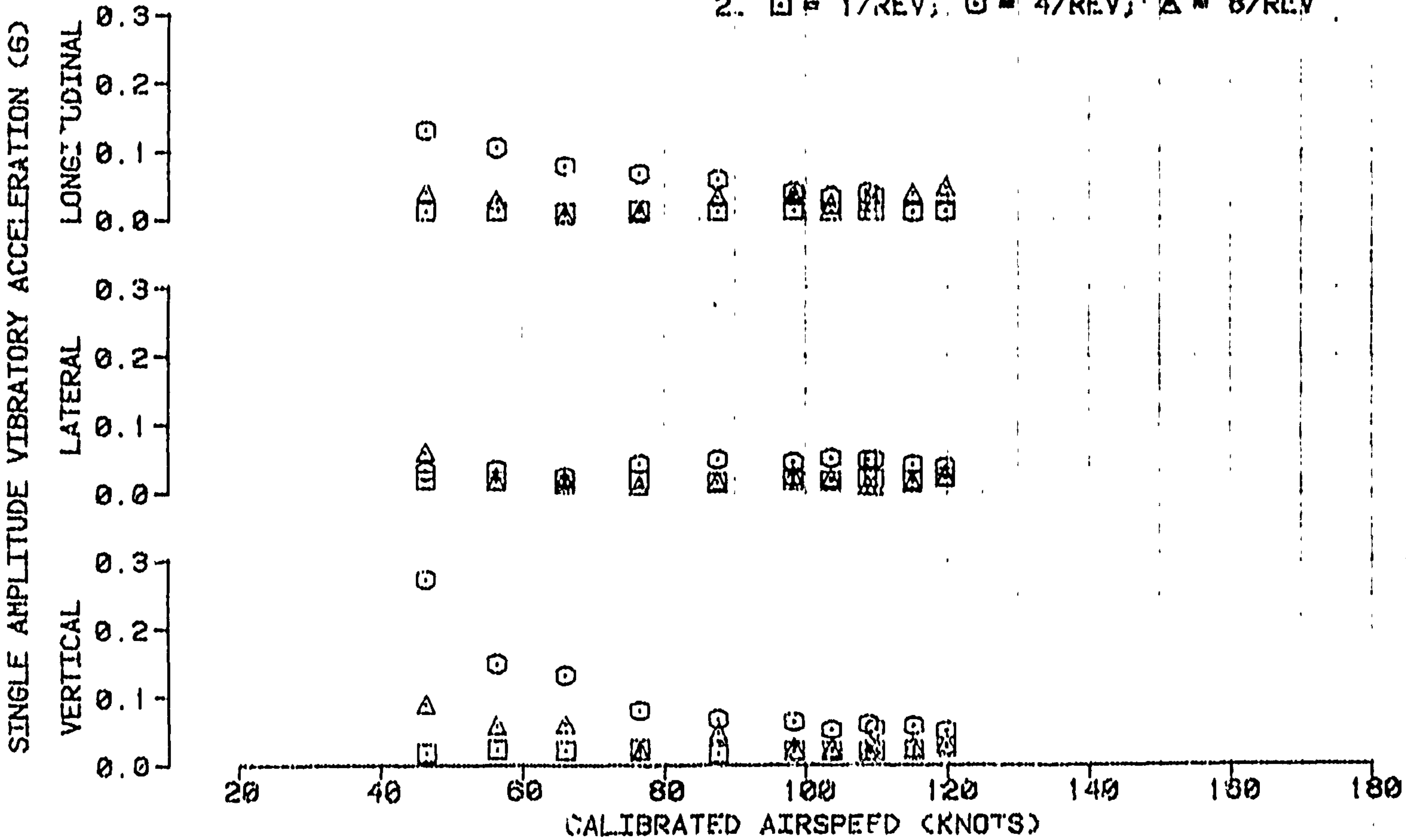


FIGURE 72.

CENTER OF GRAVITY VIBRATION CHARACTERISTICS

UH-60A USA S/N 77-22716

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALT (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	AFCS CONDITION
21330	360.2(AFT)	0.0	9380	17.5	259	LEVEL	ON

NOTES 1. NORMAL UTILITY CONFIGURATION
2. □ = 1/REV; ⊙ = 4/REV; △ = 8/REV

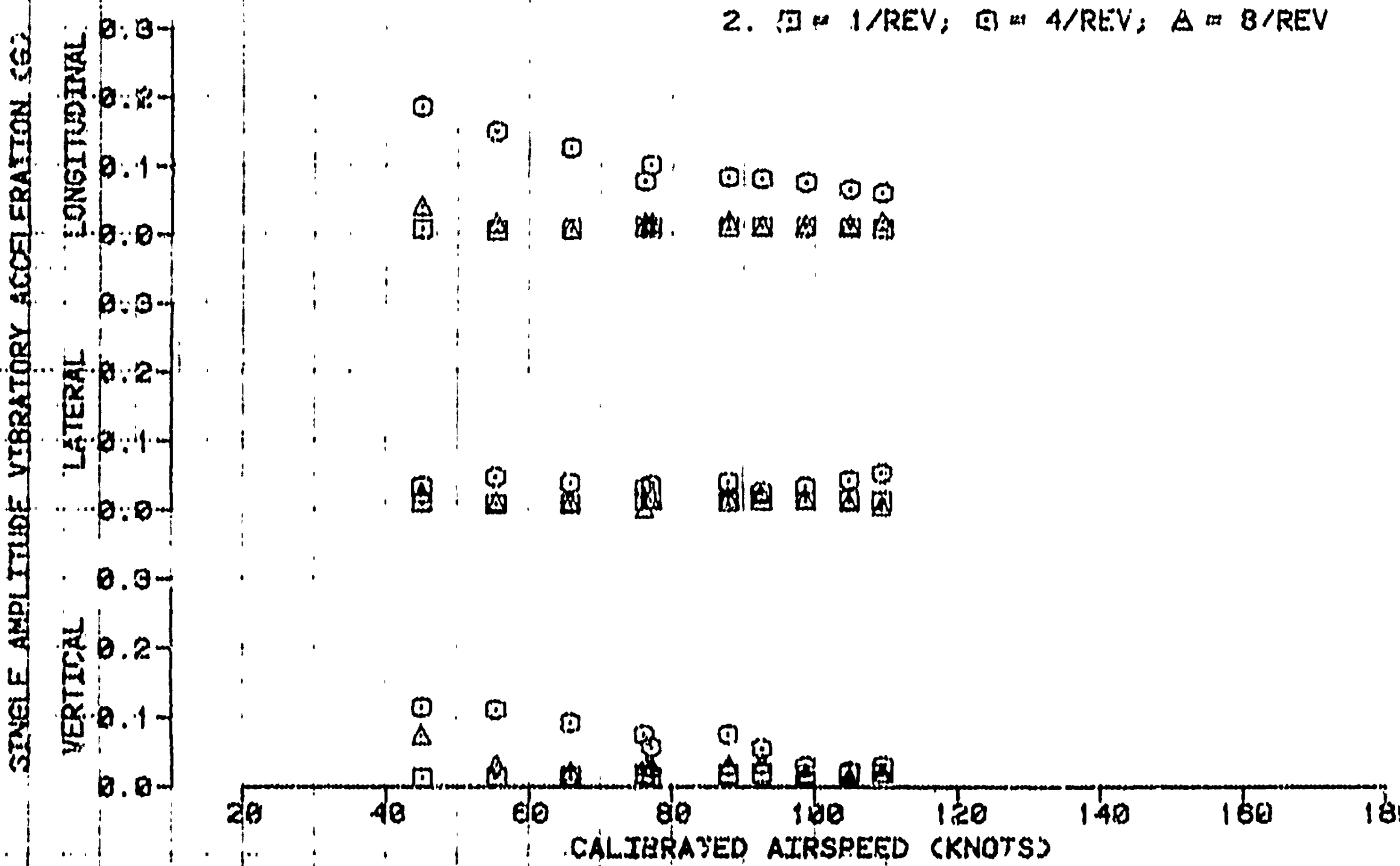
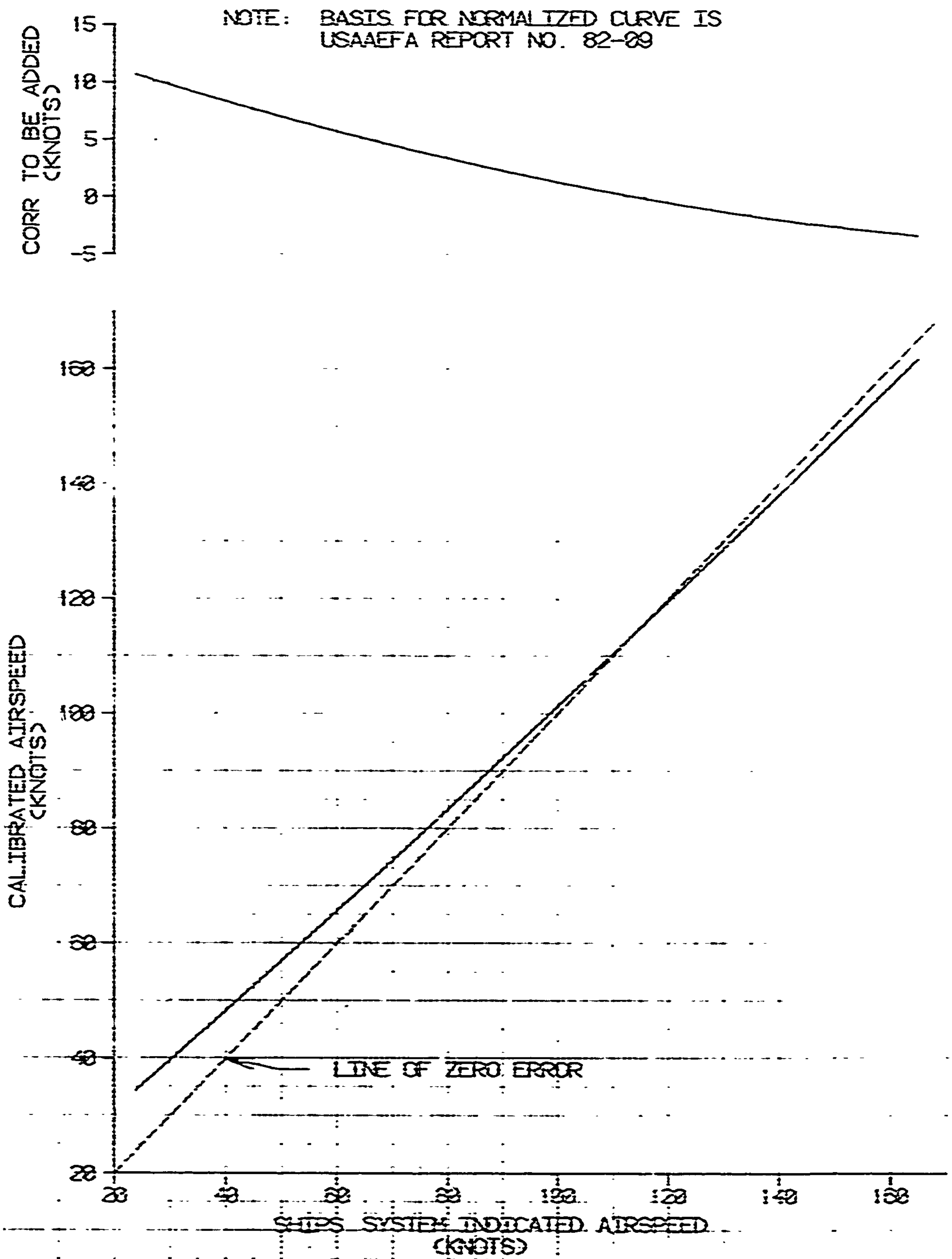


FIGURE 73
SHIPS SYSTEM AIRSPEED CALIBRATION IN LEVEL FLIGHT
UH-60A USA S/N 77-22716



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US Army Aviation Center (ATZQ-D-T, ATZQ-CDC-C, ATZQ-TSM-A, ATZQ-TSM-S, ATZQ-TSM-LH)	5
US Army Combined Arms Center (ATZL-TIE)	1
US Army Safety Center (PESC-SPA, PESC-SE)	2
US Army Cost and Economic Analysis Center (CACC-AM)	1
US Army Aviation Research and Technology Activity (AVSCOM) NASA/Ames Research Center (SAVRT-R, SAVRT-M (Library)	3
US Army Aviation Research and Technology Activity (AVSCOM) Aviation Applied Technology Directorate (SAVRT-TY-DRD SAVRT-TY-TSC (Tech Library)	2

US Army Aviation Research and Technology Activity (AVSCOM) Aeroflightdynamics Directorate (SAVR ?-D)	1
US Army Aviation Research and Technology Activity (AVSCOM) Propulsion Directorate (SAVRT-PN-D)	1
Defense Technical Information Center (FDAC)	2
US Military Academy, Department of Mechanics (Aero Group Director)	1
ASD/AFXT, ASD/ENF	2
US Army Aviation Development Test Activity (STEBG-CT)	2
Assistant Technical Director for Projects, Code: CT-24 (Mr. Joseph Dunn)	2
6520 Test Group (ENML)	1
Commander, Naval Air Systems Command (AIR 5115B, AIR 5301)	3
Defense Intelligence Agency (DIA-DT-2D)	1
US Army Aviation Systems Command (AMCPM-BH)	4
United Technologies Corporation, Sikorsky Aircraft Division (R ch Gallagher)	1